

# DBA 2014

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→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB -- Universitätsbibliothek  
→ URZ -- Universitätsrechenzentrum  
→ VLV -- Vorlesungsverzeichnis  
→ PERSSEARCH -- Personensuche



HOME Contact Studium Geowissenschaften Lehrveranstaltungen Vorträge und Links Strukturgeologie  
Rock Deformation Projects & Software Workshops Textbook XM Macros Image Macros Image Analysis

## LEHRVERANSTALTUNGEN



...ceci n'est pas "L'appel des cimes" de René Magritte...

### I2019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014

RENEE HEILBRONNER

- WO ?** Computerraum, Eingangshalle, Bernoullianum.
- ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageXM bzw. imageJ kennenlernen, die Verwendung von Macros üben (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageXM software (MacOSX)
- INHALT** Schwergewicht dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerbasierte Erkennen und Quantifizieren von Bildinhalten. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Extrapolation (2-D -> 3D) werden anwendungsorientiert vorgestellt. Methoden der Formanalyse, der Volumenschätzung sowie der Korngrößenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die, im akademischen Bereich sehr weit verbreitete Software Image XM, bzw. imageJ (alle public domain) abgestellt.
- LITERATUR**
- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. *(Sammelbestellung möglich)*
  - Haberäcker, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
  - Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing, Academic Press, New York. Computers & Geosciences Journal.
- INTERNET** [adim.unibas.ch](http://adim.unibas.ch)  
→ Phil II Geowissenschaften → I2019-01 - Digitale Bildanalyse

(← back)

TROMSØ GEO-IMAGING

→ TROMSØ CRUSTAL DYNAMICS HOMEPAGE (English)  
→ TROMSØ GEOLOGY HOMEPAGE (Norwegian)  
→ TROMSØ UNIVERSITY HOMEPAGE (English)



<http://earth.unibas.ch/micro/>

# Ziel der Vorlesung

VORLESUNGSVERZEICHNIS ONLINE

15.09.2014

12019-01 Vorlesung mit Übungen: Digitale Bildanalyse 2 KP

Dozierende **Renée Heilbronner** (renee.heilbronner@unibas.ch)

Zeit Montag, 14.00-16.00 Bernoullianum 32

Findet im CR 24 B statt (Bernoullianum, Parterre).

Beginndatum 15.09.2014

Teilnahme **Lernziele**

Anmeldung zur Lehrveranstaltung

Intervall

Angebotsmuster

Anbietende Organisationseinheit

Module

Lernziele **Inhalt**

Inhalt

Literatur

Weblink

Leistungsüberprüfung

Skala

Studierende sollen das Bildanalyse Programm ImageSXM bzw. imagej kennenlernen, die Verwendung von Macros üben (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen.

Schwergewicht dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerbasierte Erkennen und Quantifizieren von Bildinhalten. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Extrapolation (2-D → 3D) werden anwendungsorientiert vorgestellt. Methoden der Formanalyse, der Volumenschätzung sowie der Korngrößenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist weitgehend auf die, im akademischen Bereich sehr verbreitete Software Image SXM und imagej/Fiji (alle public domain) abgestellt.

Lehrveranst.-begleitend

1-6 0,5



# Literatur

Praktische Anwendung:

Heilbronner, R. & Barrett, S.D. (2013).  
Image Analysis in Earth Sciences. Springer Verlag.

Theoretischer Hintergrund:

Peter Haberäcker (1991)  
Digitale Bildverarbeitung (4. durchgesehene Auflage). Hanser Studienbücher.

Gonzalez, R.C. & Woods, R.E. (2008)  
Digital Image Processing (3rd edition). Prentice Hall.

Burger, W. & Burge M.J. (2009)  
Principles of Digital Image Processing – Fundamental Techniques. Springer-Verlag.

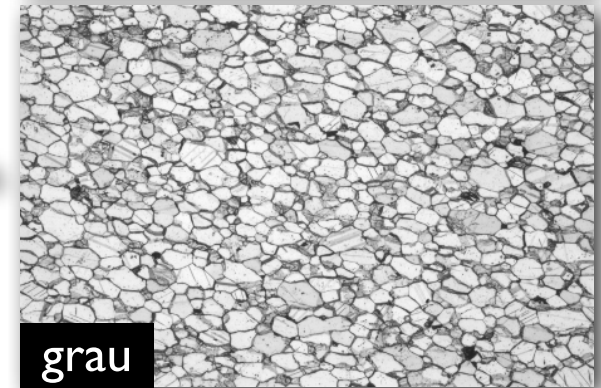
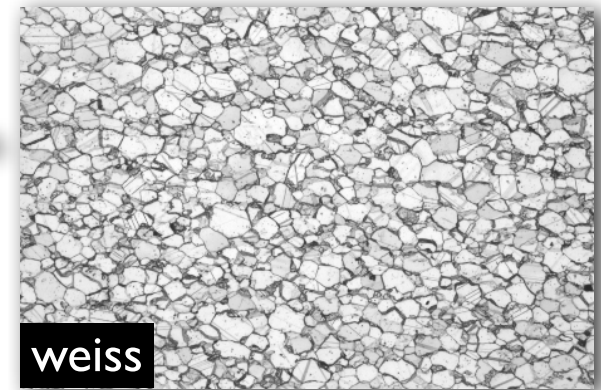
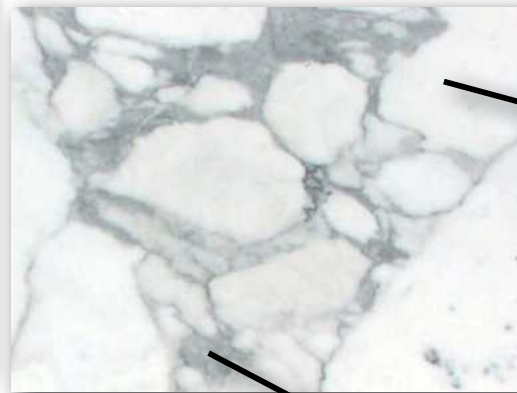
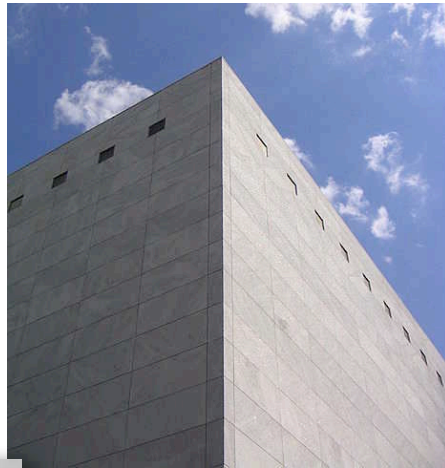
web:

<http://imagingbook.com>

[http://www.imageprocessingplace.com/root\\_files\\_V3/students/students.htm](http://www.imageprocessingplace.com/root_files_V3/students/students.htm)

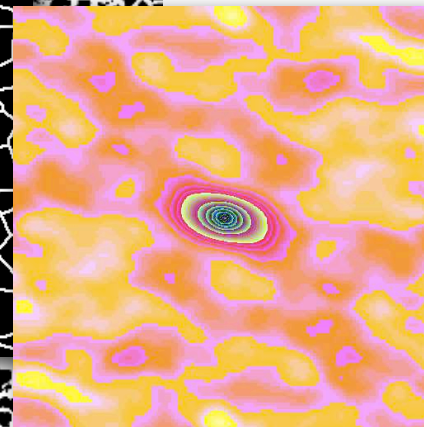
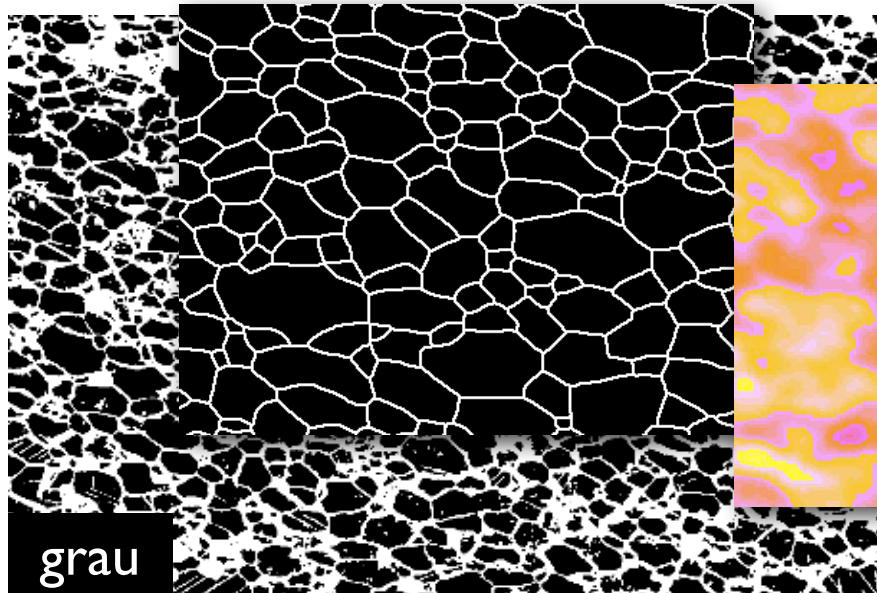
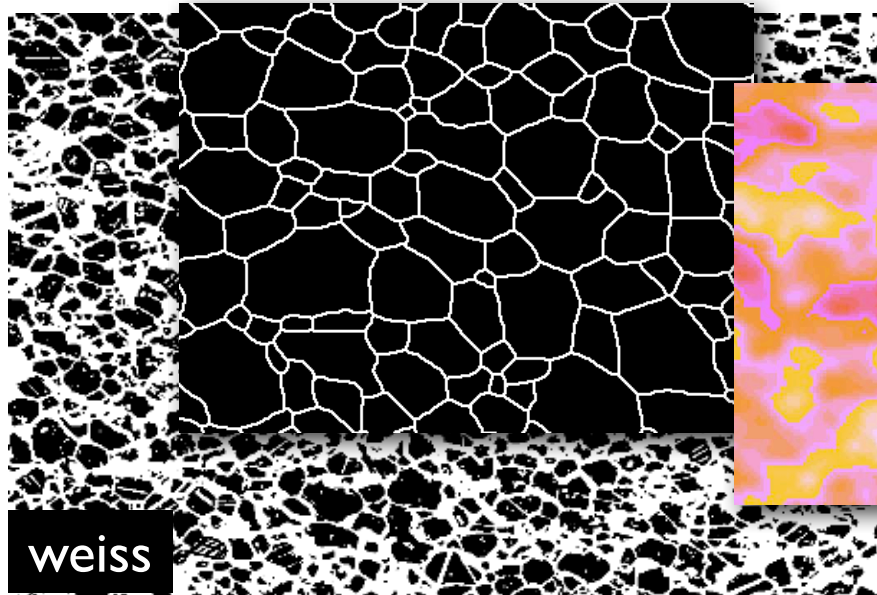
<http://www.cambridgeincolour.com>

# was ist Bildanalyse ?



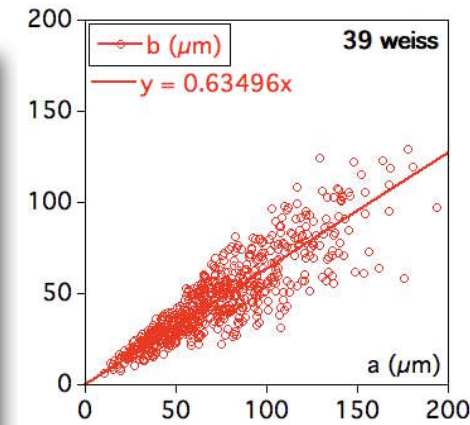
# ein Beispiel

ACF

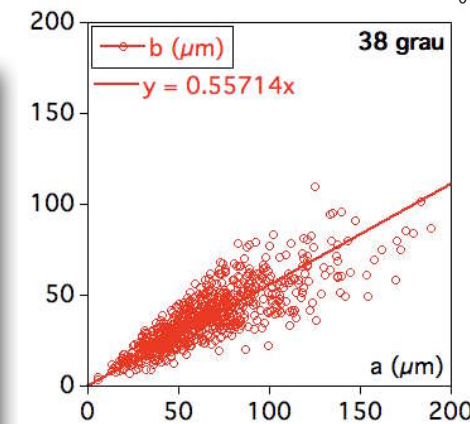
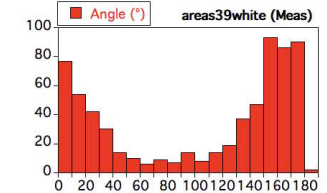


Kornform

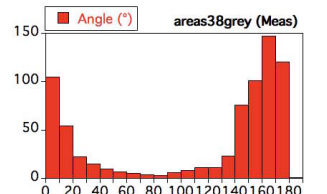
Ausrichtung



Durchmesser = 57.6 µm  
 Aspect ratio = 1.61  
 Orientierung = 104°



Durchmesser = 49.7 µm  
 Aspect ratio = 1.78  
 Orientierung = 114°



# Semesterfahrplan

			Freitag CR 14-17	Montag CR 14-17
	Thema	Doz.	Gruppe A	Gruppe B
1	Images for image analysis - intro: ImageSXM	RH	19-Sep-2014	22-Sep-2014
2	Digital Images - Pixels - LUTs	RH	26-Sep-2014	29-Sep-2014
3	Explore / pre-process digital images - intro: imagej	RK	3-Oct-2014	6-Oct-2014
4	POP segmentation - post-processing	RK	10-Oct-2014	13-Oct-2014
5	Mathem./Punkt-Operationen Verschneide-Operationen	RH	17-Oct-2014	
		RH		27-Oct-2014
6	Filtern - Kantendetektion - NOP segmentation	RH	31-Oct-2014	3-Nov-2014
7	Analyse: segments - best-fit ellipses - property maps	RH	7-Nov-2014	10-Nov-2014
8	Fourier-Transformationen Autokorrelation	RH	14-Nov-2014	17-Nov-2014
9	Korngrößen-Analyse - Stereologie - Kontaktflächen	RH	21-Nov-2014	24-Nov-2014
Test			5-Dec-2014	8-Dec-2014

pro Nachmittag: 1. Teil: Vorlesung (Einführung in das Thema) - 2. Teil: Übungen  
Besprechung der Übungen am Anfang der nächsten Vorlesung

# Bilder

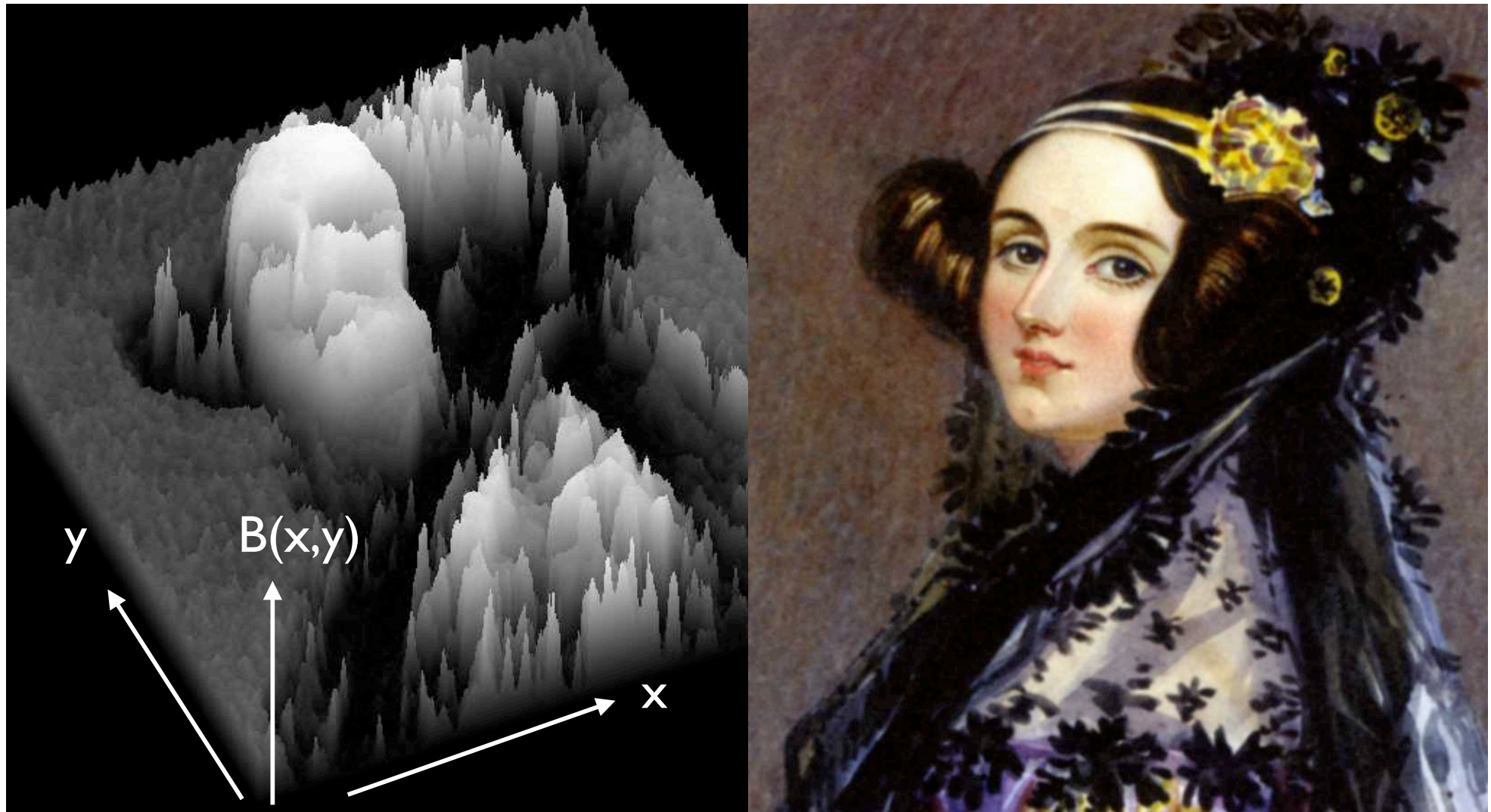


# was ist ein Bild ?



René Magritte: La trahison des images (1928–1929)

# was sehen wir ? - nicht das Bild !

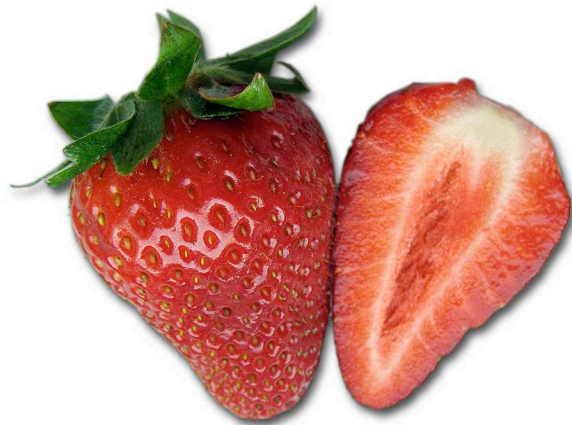


ein Bild als Helligkeitsverteilung  $B(x,y)$ ...

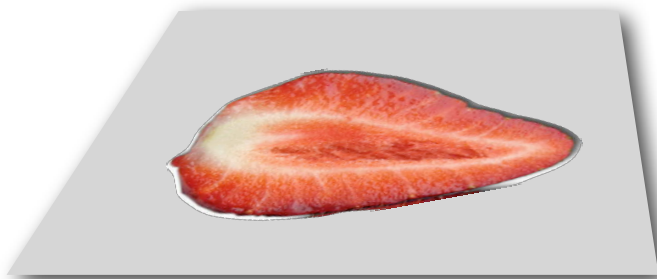
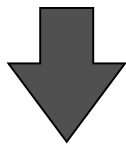
Augusta Ada King, Countess of Lovelace  
(10 December 1815 - 27 November 1852) !!



# vom Objekt zum Bild



3D ~2D Objekte



2D Bild

## Geräte / Verfahren / Quellen:

Photographische (Digital-) Kamera

Flachbettscanner (Auflicht / Durchlicht)

Dia Scanner (Dünnschliffe)

Lichtmikroskop (Polarisation)

Elektronenmikroskop (TEM)

Rasterelektronenmikroskop (SEM / SE, BSE)

Mikrosonde (element mapping)

Kathodolumineszenz (LM, SEM)

Satelliten (Remote Sensing)

Digitale Geländemodelle (Geodaten)

Tomographie (Röntgen-, seismische, nanoCT)

Publikationen / Bilddatenbanken

....



# Aufschluss- und Makrophotographie



3D Auflicht



Durchlicht



~2D Auflicht





# Flachbettscanner



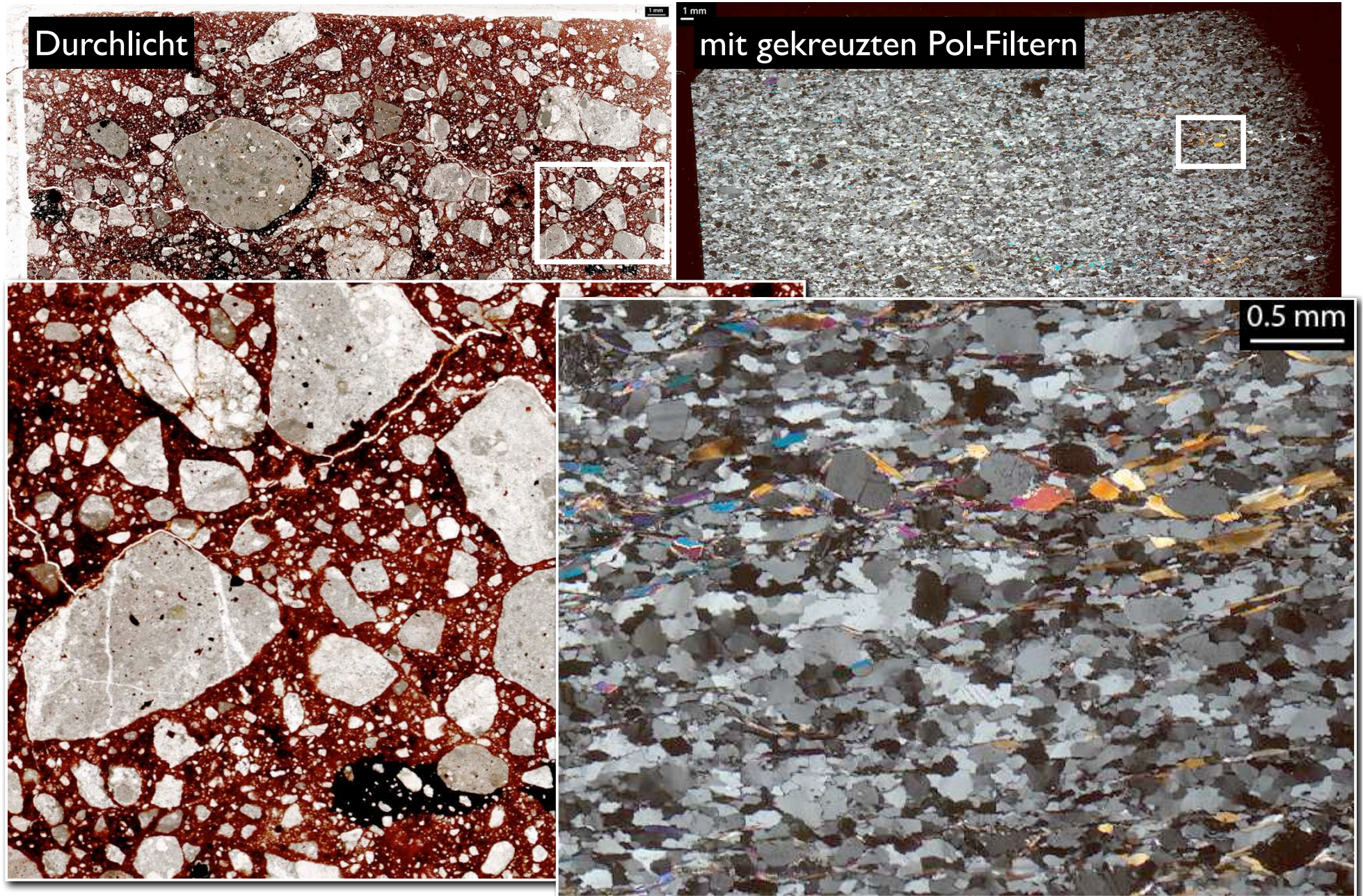
Auflicht



Durchlicht

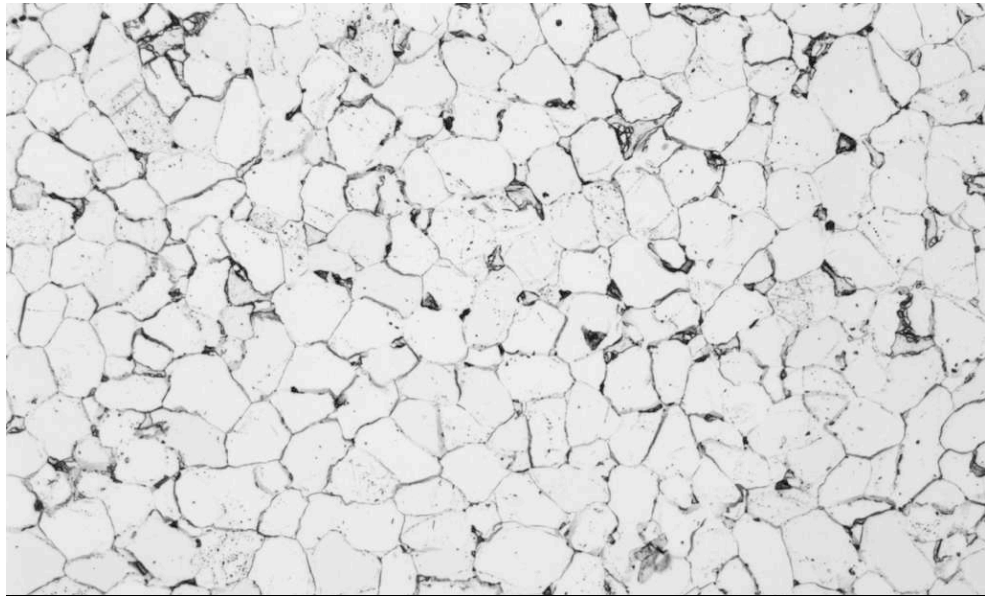


# Dünnschliffe im Dia Scanner

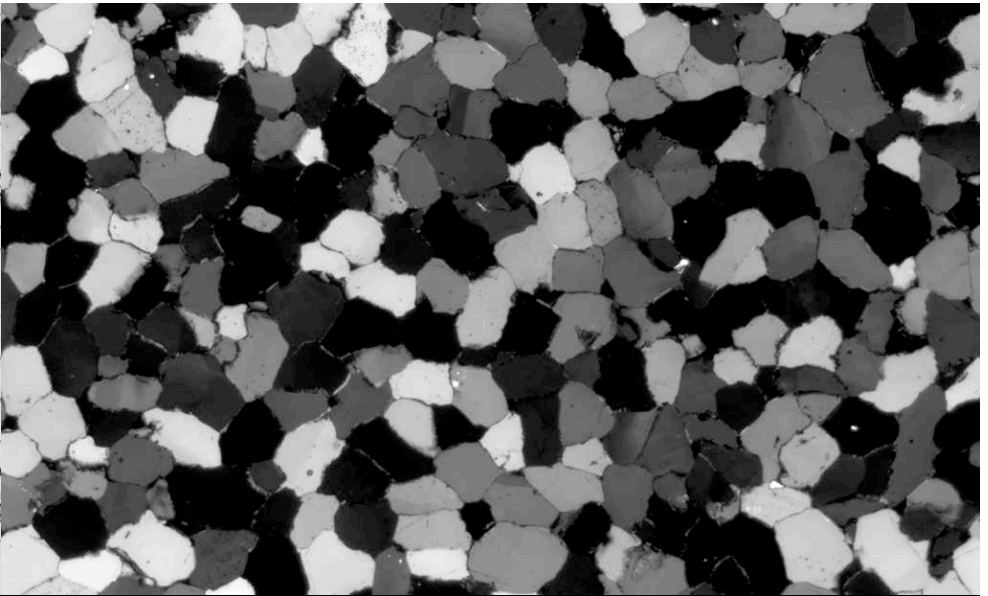




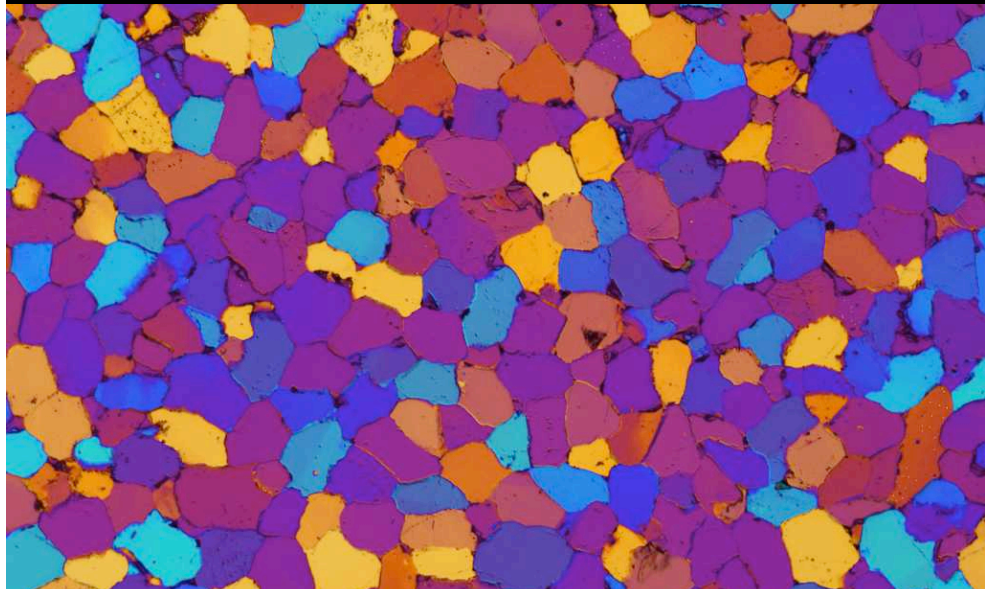
# Polarisationsmikroskopie



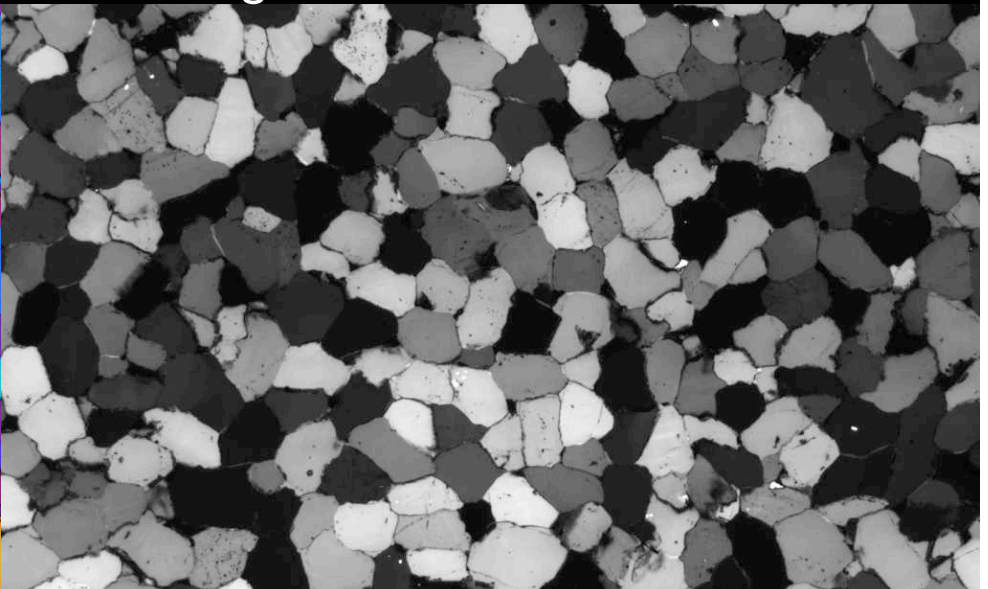
Durchlicht



gekrenzte Polarisatoren



gekrenzte Polarisatoren, Lambda-Platte



Zirkularpolarisation



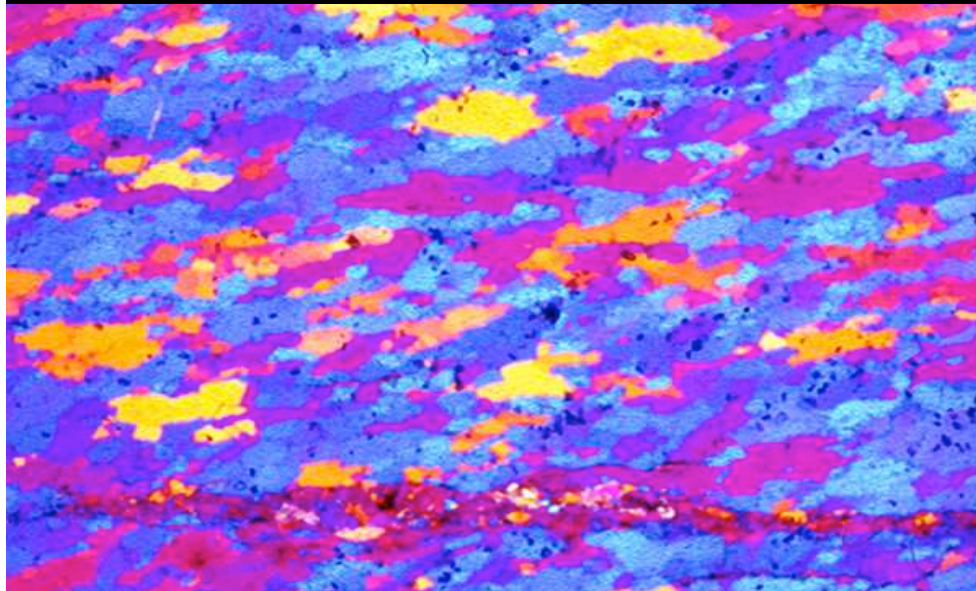
# Polarisationsmikroskopie



Durchlicht



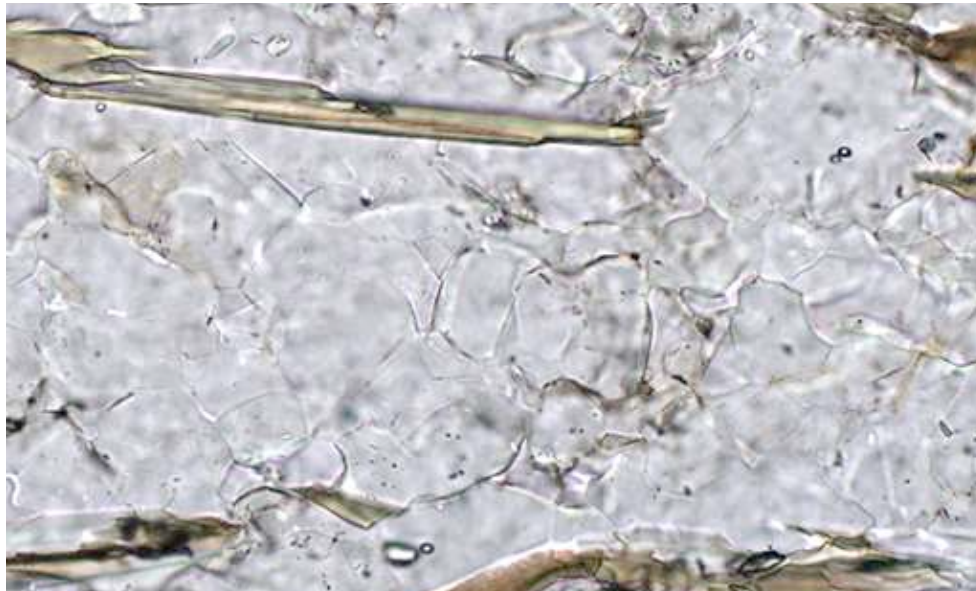
gekrenzte Polarisatoren



gekrenzte Polarisatoren, Lambda-Platte



# Mikroskopie LM, SEM / BSE



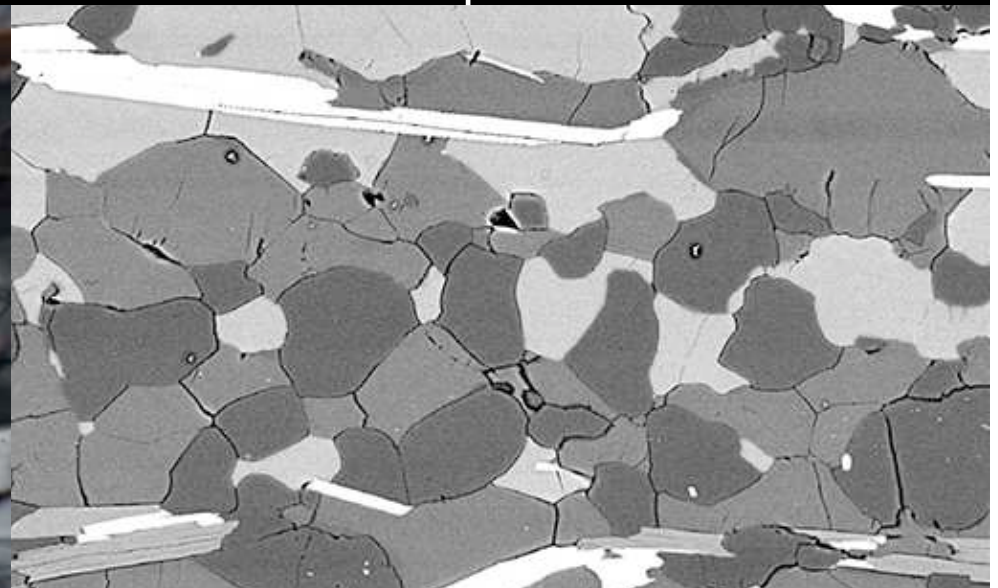
Durchlicht



Zirkularpolarisation



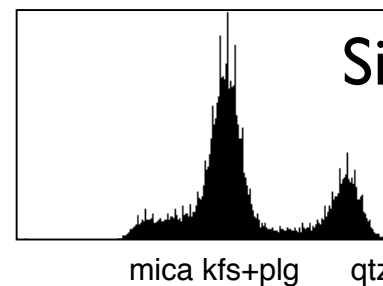
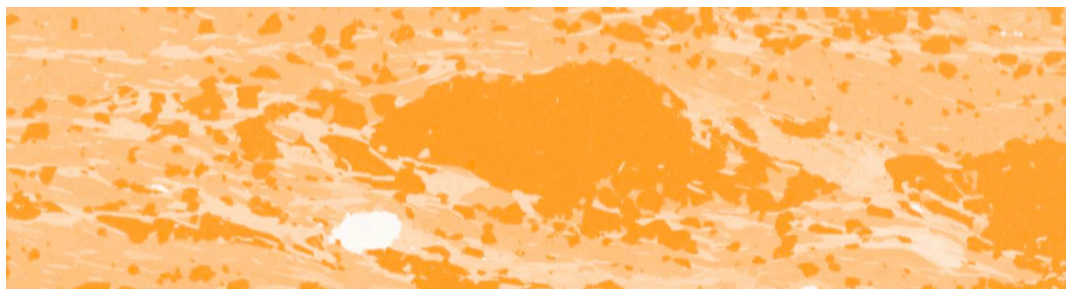
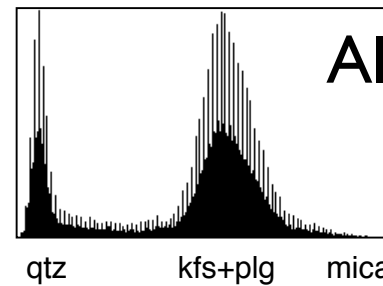
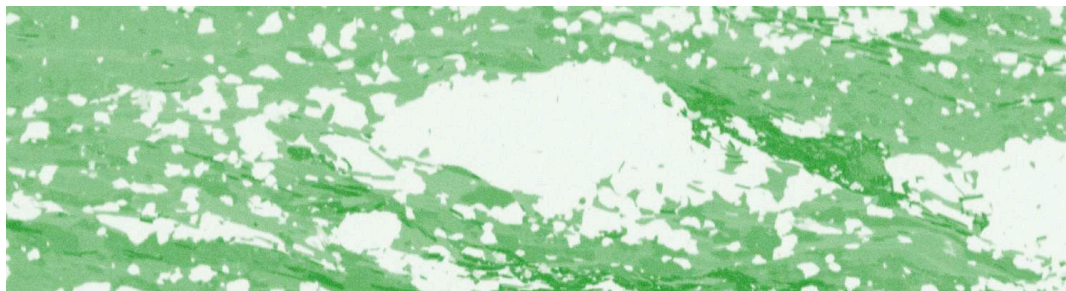
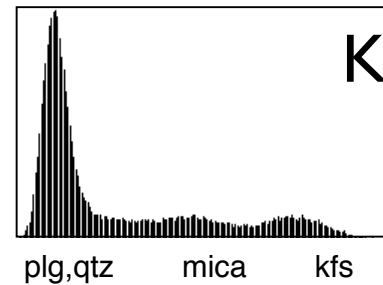
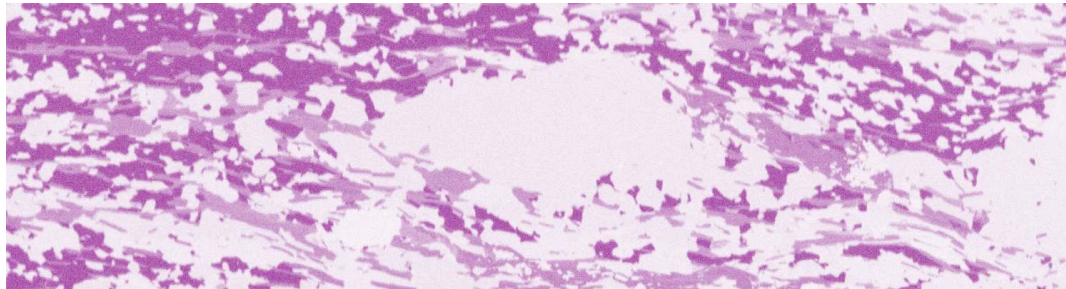
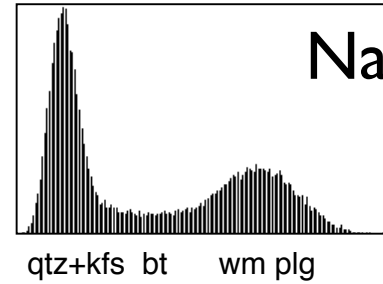
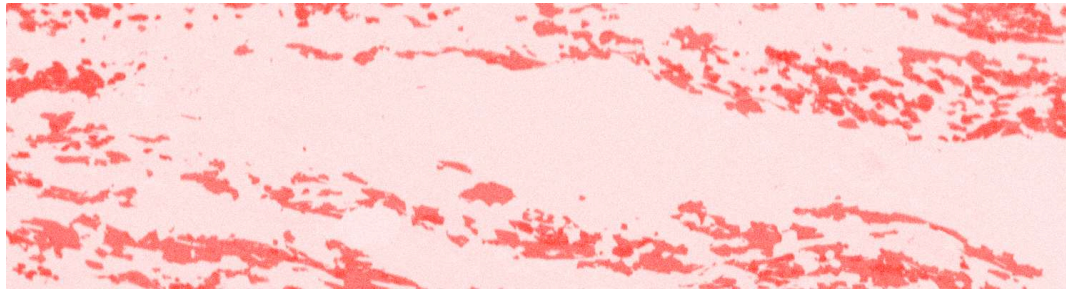
gekreuzte Polarisatoren



SEM / BSE (Z-Kontrast)



# Element Verteilungsbilder



EDX  
Energiedispersive  
Analyse

Konzentration  
dunkel = hoch  
hell = tief



# Kathodolumineszenz



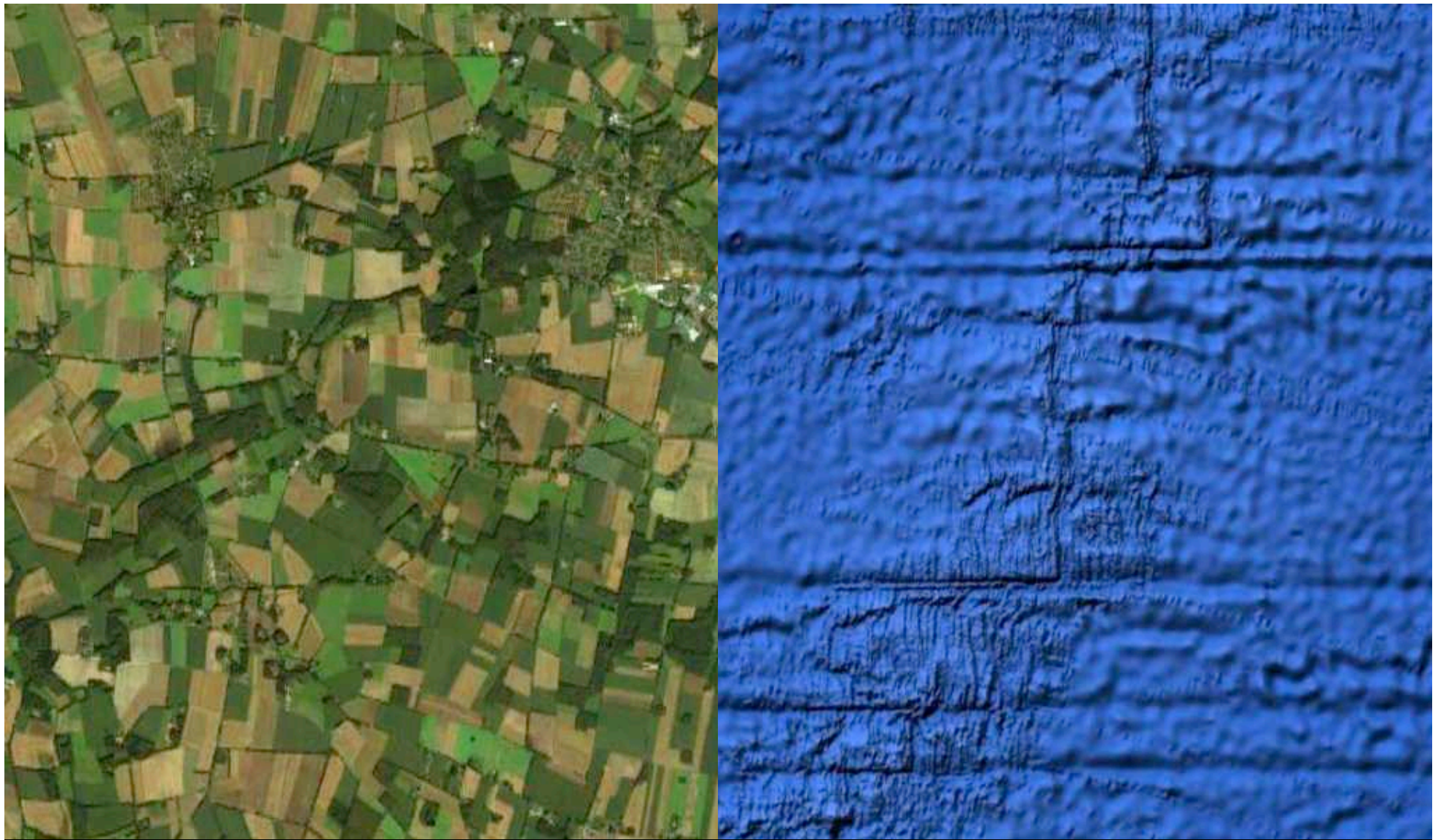
gekreuzte Polarisatoren

Kathodolumineszenz

schwarz = Quarz  
bläulich = Kalifeldspat  
rot = Plagioklas



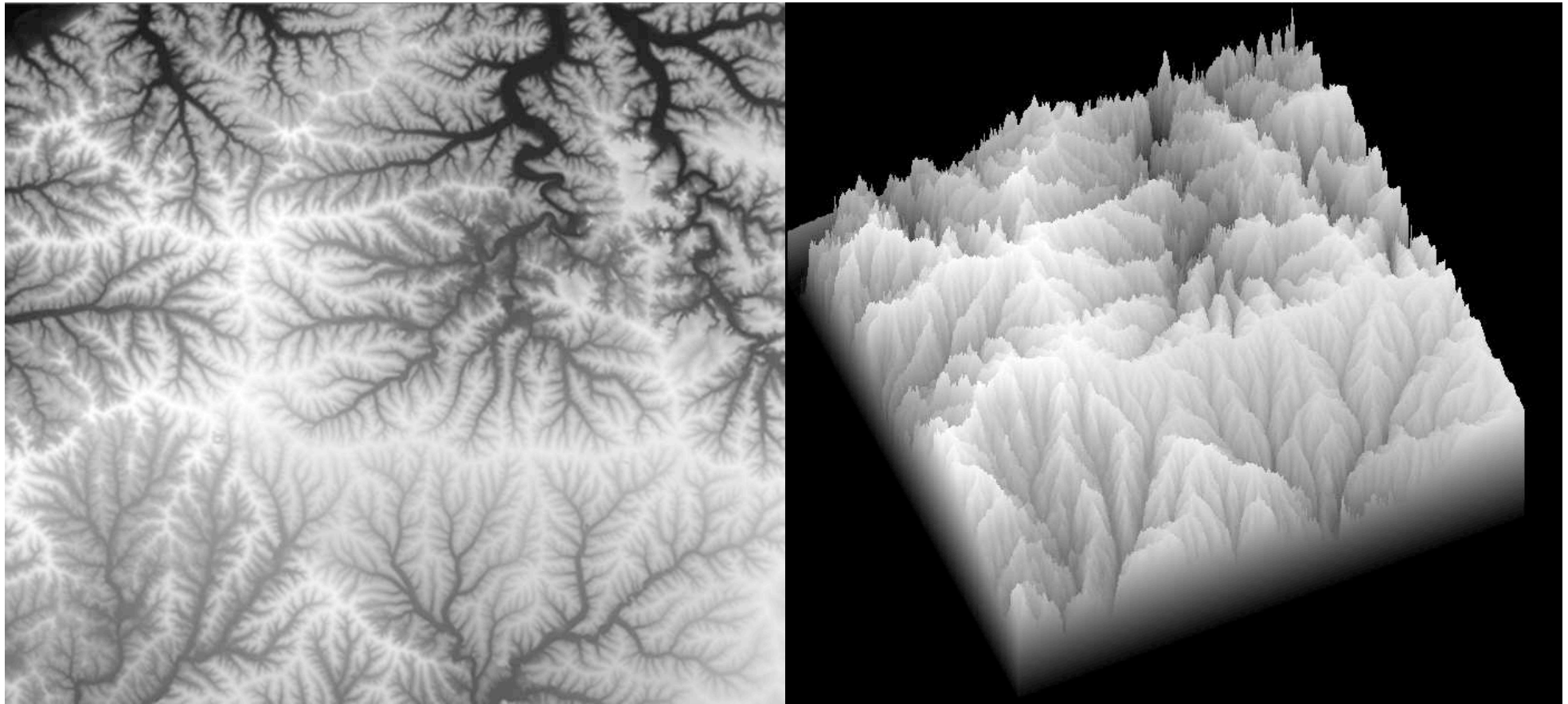
# Google Earth



Felder bei Cappeln, S von Cloppenburg

Mittelatlantischer Rücken, S von St. Helena

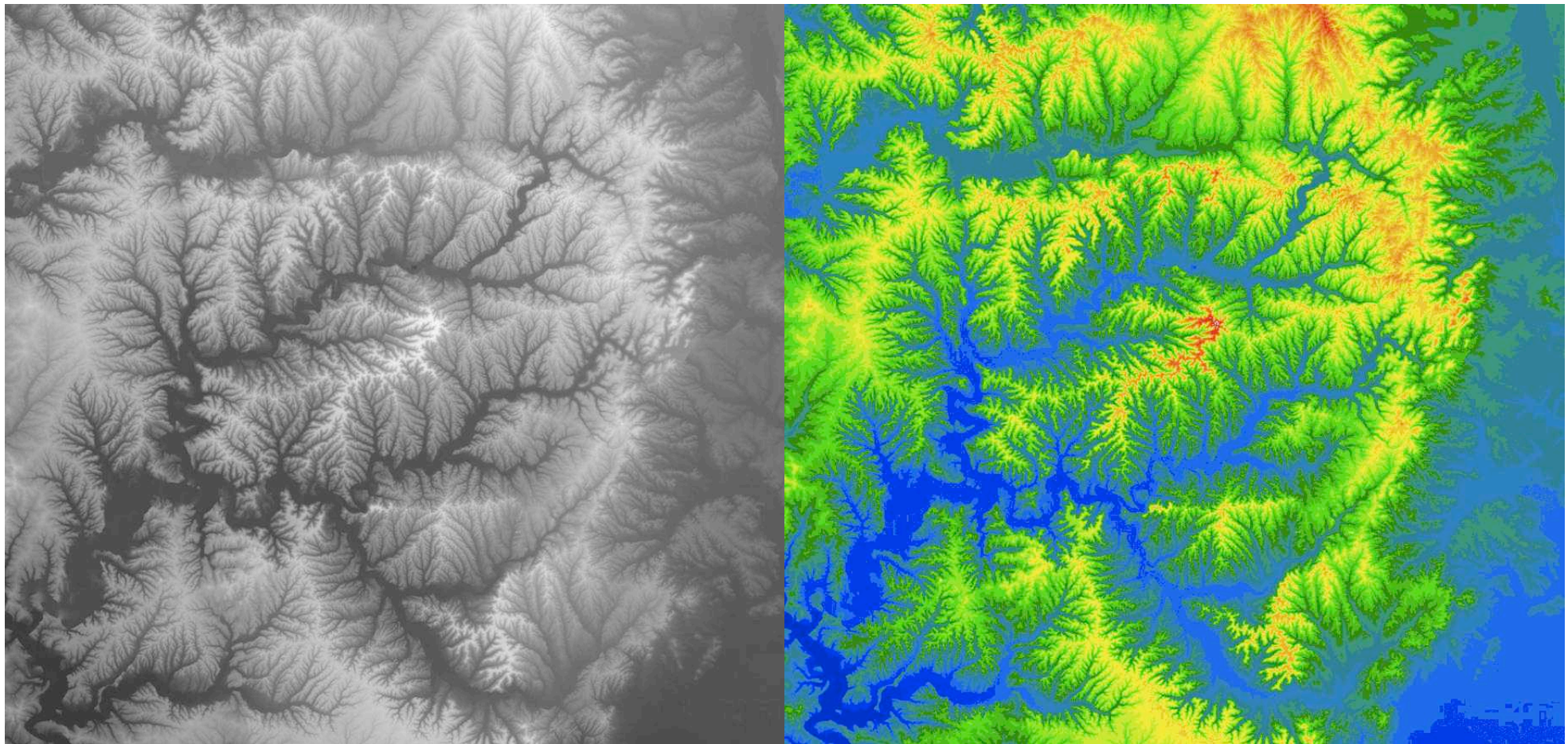
# digital elevation model



Northeast corner of Grant County, Wisconsin, DEM by Sam Batzli  
Space Science and engineering Center, Univ. Wisconsin-Madison  
<http://www.ssec.wisc.edu/news/articles/2702>



# digital elevation model

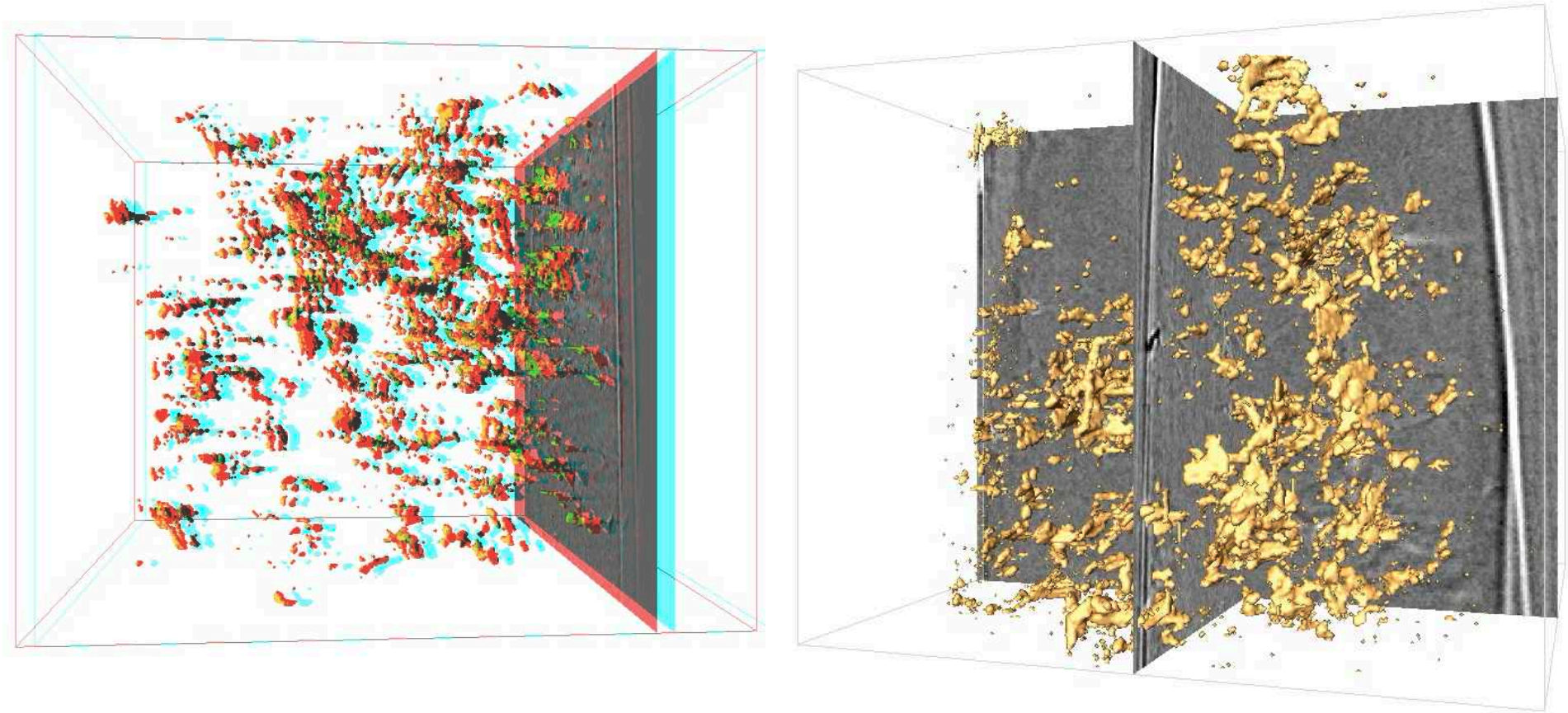


Digital Elevation Model (DEM) displaying parts of Monroe, Brown, Bartholomew, Lawrence, and Jackson Counties.  
Indiana GIS News, Indiana Geographic Information Council  
<http://www.igic.org/news/index.php?itemid=500>





# nano CT X-ray photon beam



Porenraum in deformiertem Quarzpulver  
Advanced Photon Source Argonne National Laboratory (Illinois)  
APS electron accelerator



# Publikation

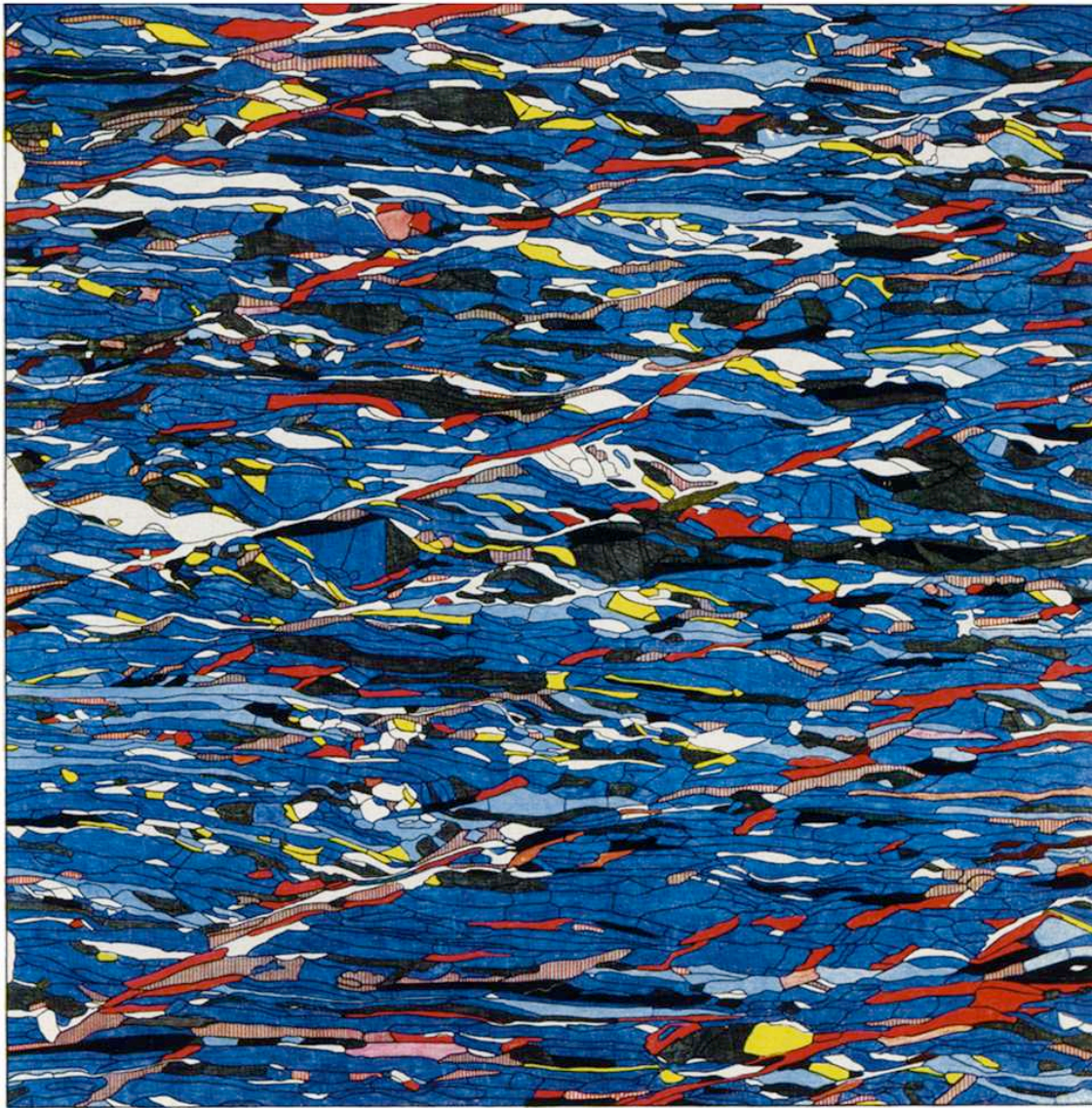


PLATE I.b. Quartzite, Raintal, Bozen; section  $\perp$  r a;  
2493 quartz-axes;  $\times 45$  A.V.A. (Ramsauer)

Achsenverteilungsanalyse (A.V.A.):  
c-Achsen Orientierungsbild

aus:  
Bruno Sander, 1930. Gefügekunde  
der Gesteine. Springer, Wien.



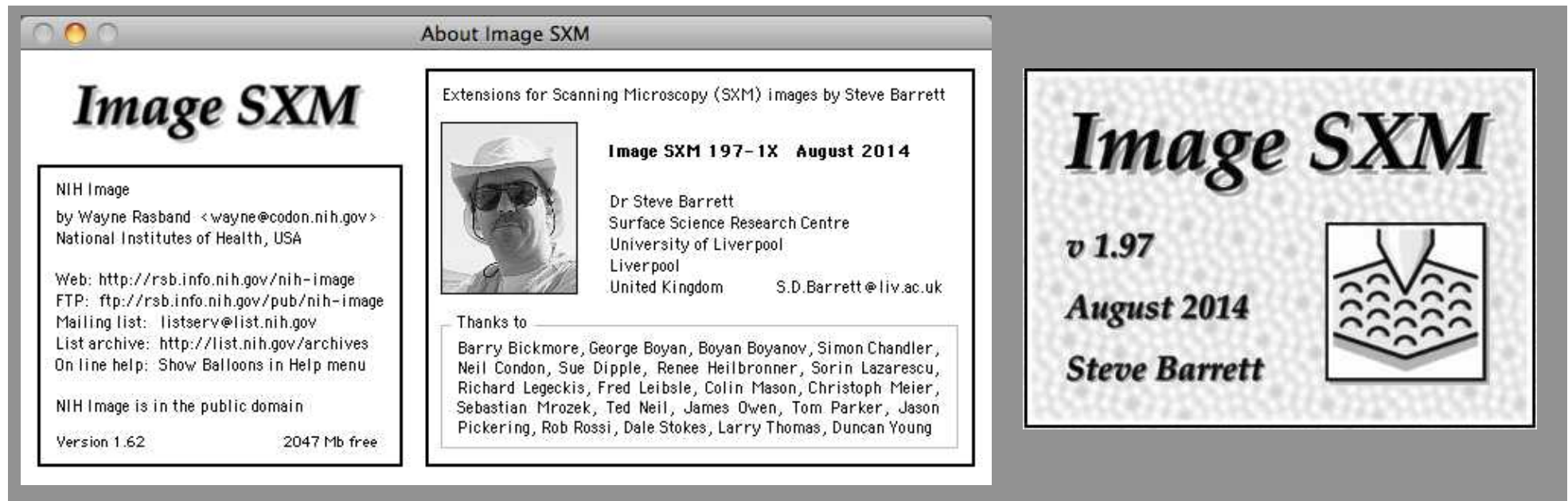


# Software

# Image SXM (Pascal)

MacOSX - software used in workshop:

<http://www.liv.ac.uk/~sdb/ImageSXM/>




The image shows a screenshot of a Mac OS X window titled "About Image SXM". The window contains the following information:

- Image SXM**
- NIH Image  
by Wayne Rasband <wayne@codon.nih.gov>  
National Institutes of Health, USA
- Web: <http://rsb.info.nih.gov/nih-image>  
FTP: <ftp://rsb.info.nih.gov/pub/nih-image>  
Mailing list: [listserv@list.nih.gov](mailto:listserv@list.nih.gov)  
List archive: <http://list.nih.gov/archives>  
On line help: Show Balloons in Help menu
- NIH Image is in the public domain
- Version 1.62      2047 Mb free

Extensions for Scanning Microscopy (SXM) images by Steve Barrett

**Image SXM 197-1X August 2014**

 Dr Steve Barrett  
Surface Science Research Centre  
University of Liverpool  
Liverpool  
United Kingdom      S.D.Barrett@liv.ac.uk

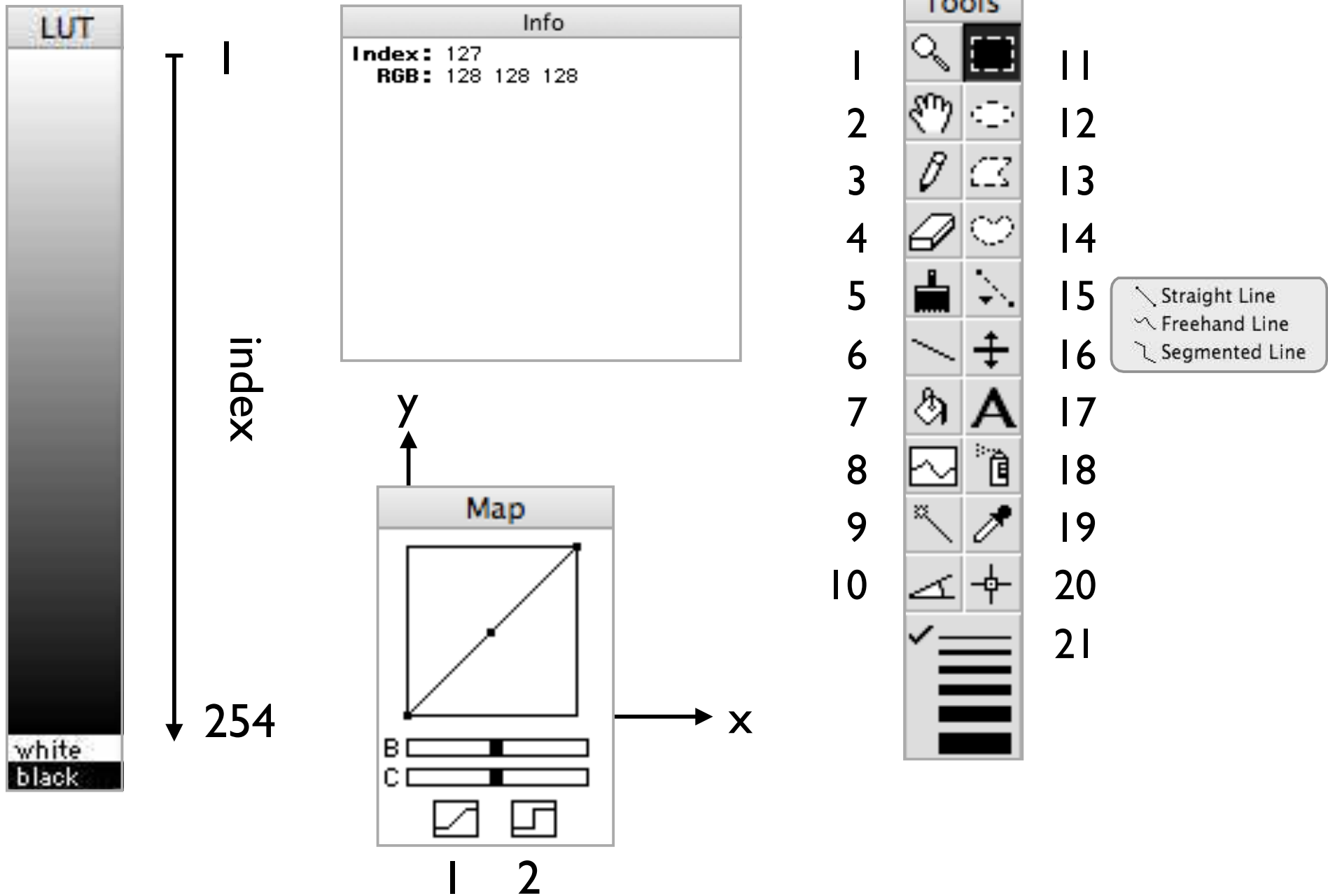
Thanks to

Barry Bickmore, George Boyan, Boyan Boyanov, Simon Chandler, Neil Condon, Sue Dipple, Renee Heilbronner, Sorin Lazarescu, Richard Legeckis, Fred Leibsle, Colin Mason, Christoph Meier, Sebastian Mrozek, Ted Neil, James Owen, Tom Parker, Jason Pickering, Rob Rossi, Dale Stokes, Larry Thomas, Duncan Young

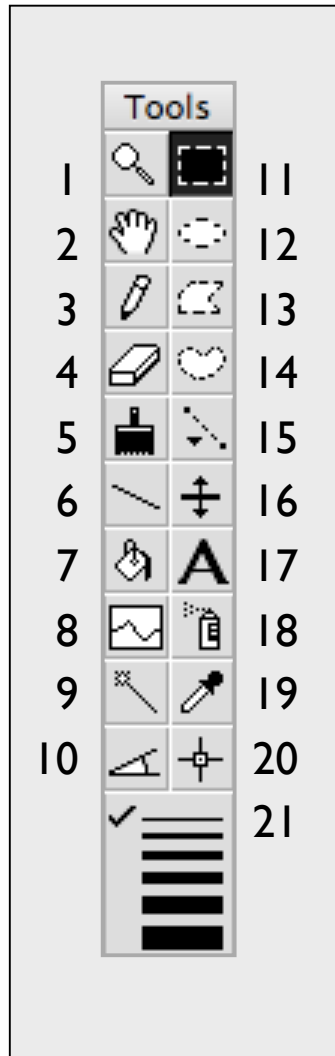
To the right of the window is a promotional graphic for Image SXM v 1.97, August 2014, by Steve Barrett. The graphic features the text "Image SXM v 1.97 August 2014 Steve Barrett" and a logo consisting of a stylized book with a microscope objective lens above it.

Image SXM is a version of the public domain image analysis software NIH Image that has been extended to handle the loading, display and analysis of scanning microscope images. Image SXM supports SAM, SCM, SEM, SFM, SLM, SNOM, SPM and STM images

# Image SXM windows

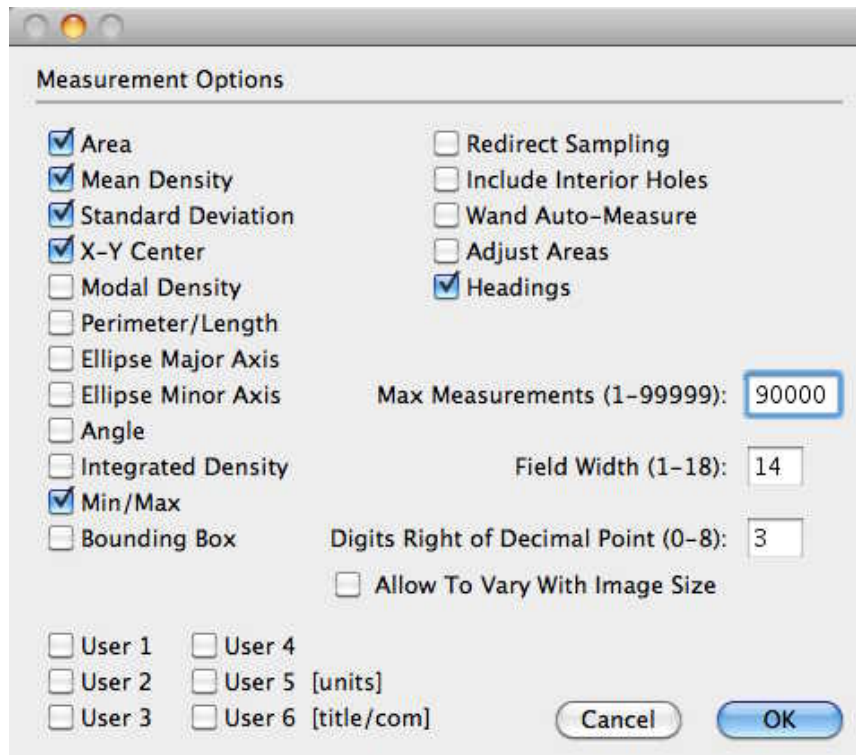
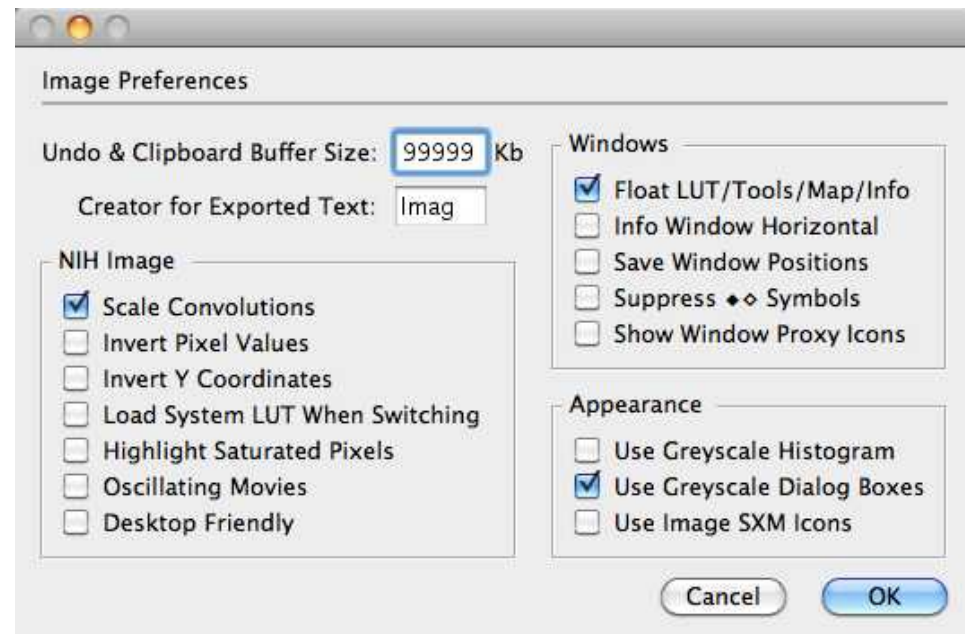
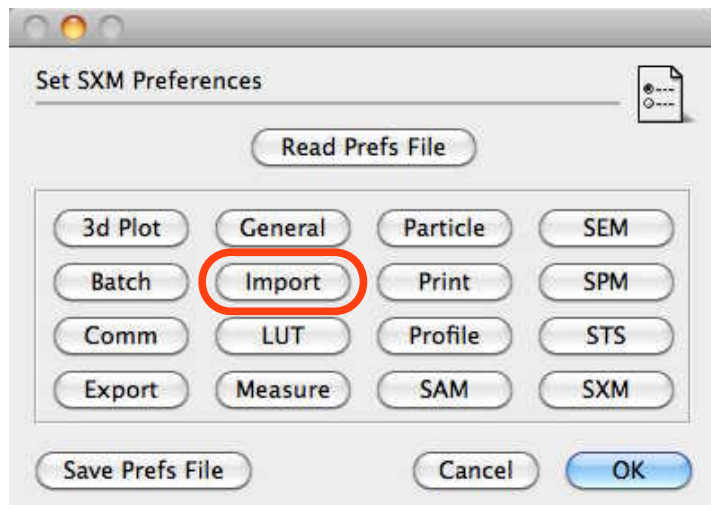


# Tools

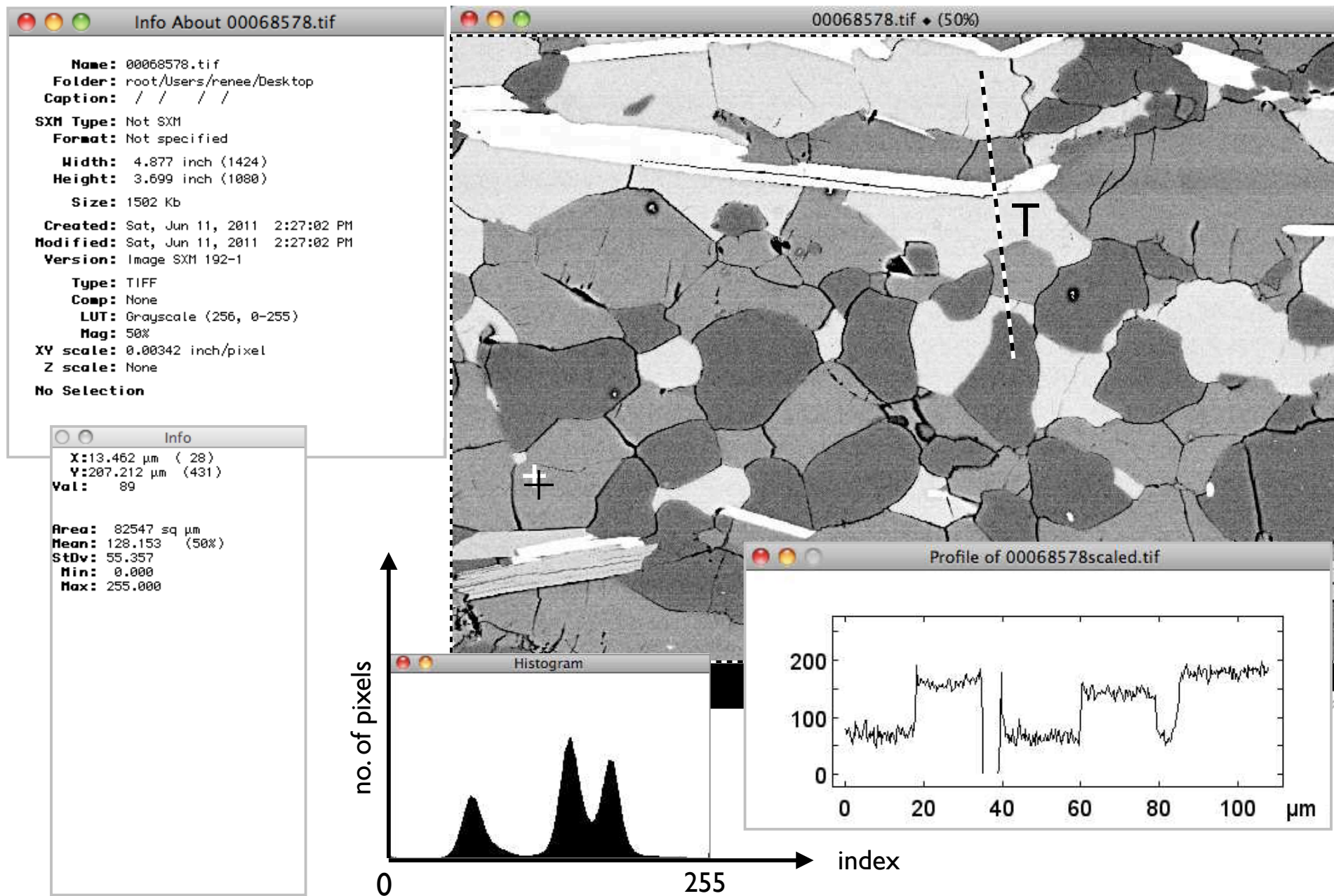


- |    |                                    |    |                            |
|----|------------------------------------|----|----------------------------|
| 1  | Magnifying Glass                   | 11 | Rectangular Selection Tool |
| 2  | Scrolling Tool (Grabber)           | 12 | Oval Selection Tool        |
| 3  | Pencil                             | 13 | Polygonal Selection Tool   |
| 4  | Eraser                             | 14 | Freehand Selection Tool    |
| 5  | Paint Brush                        | 15 | Line Selection Tools       |
| 6  | Line Drawing                       | 16 | LUT Tool                   |
| 7  | Paint Bucket Tool                  | 17 | Text Tool                  |
| 8  | Density Profile Tool               | 18 | Spray Can                  |
| 9  | Automatic Outlining<br>(Wand) Tool | 19 | Eyedropper                 |
| 10 | Angle Tool                         | 20 | Cross Hair Tool            |
|    |                                    | 21 | Line and frame widths      |

# Preferences & options

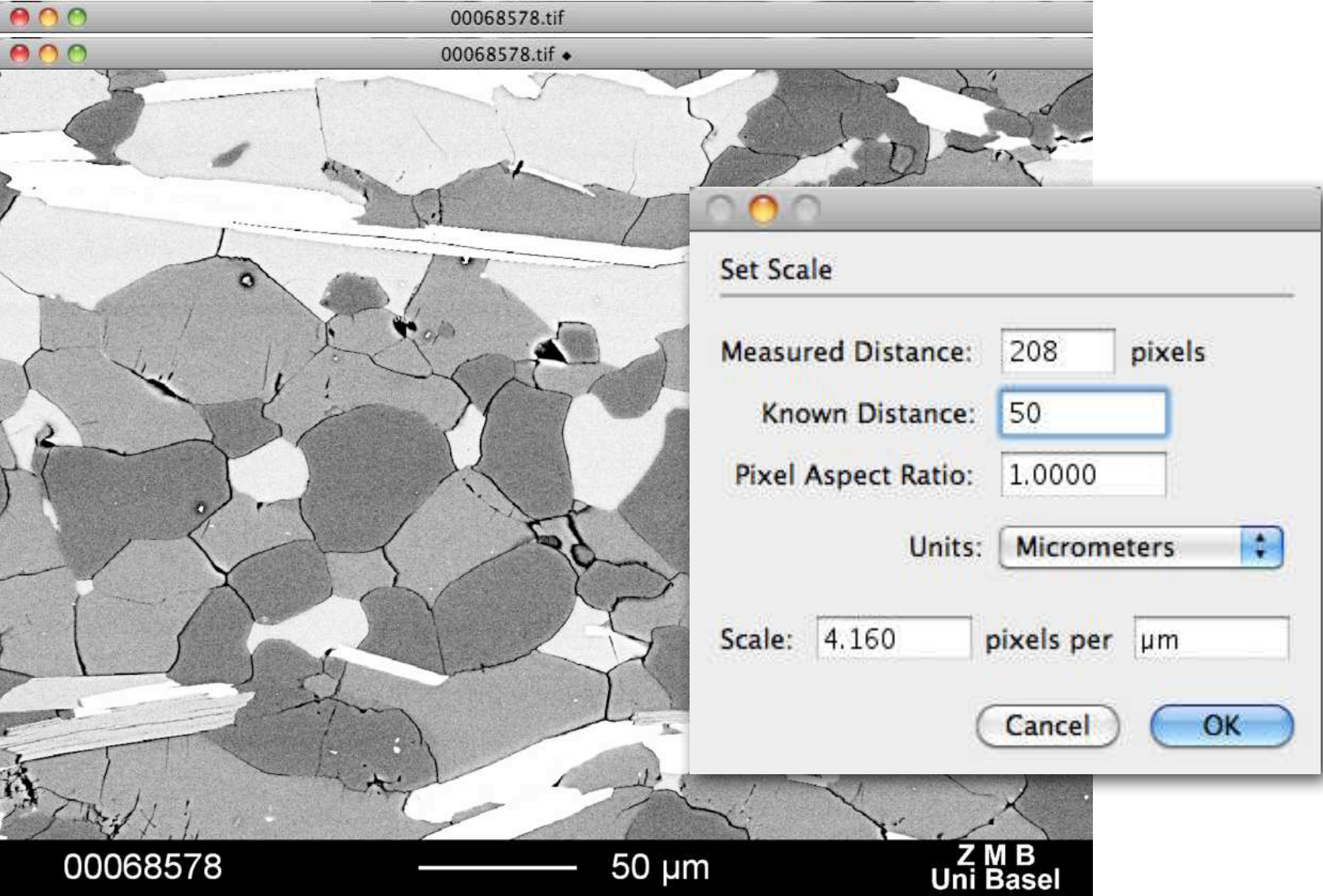


# Image info



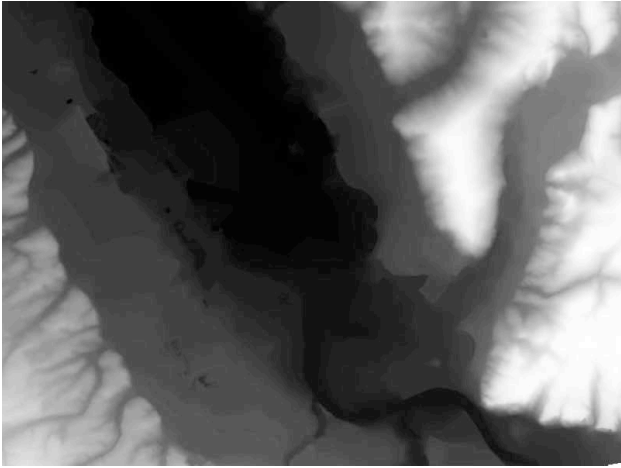


# Scaling

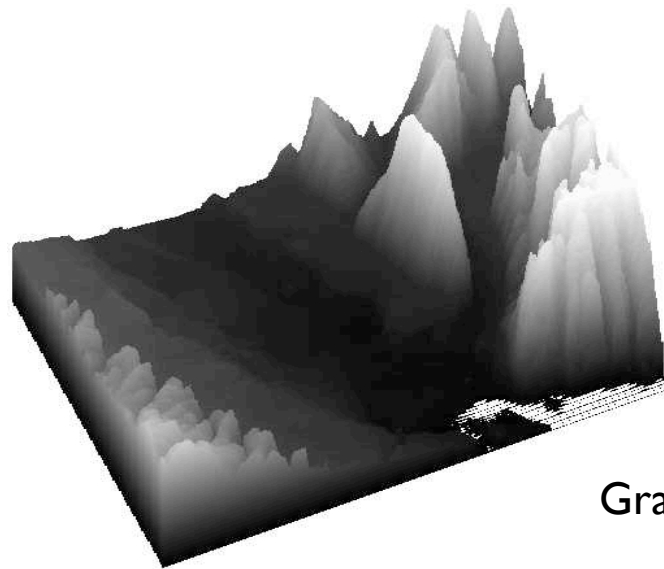




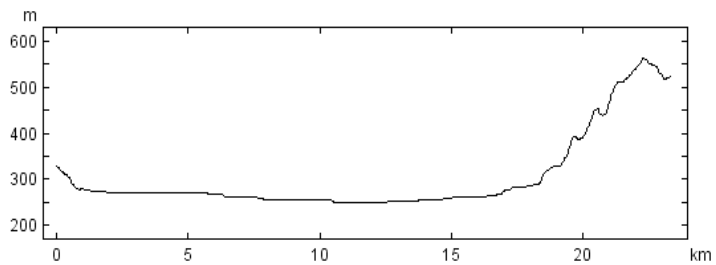
# Calibrating



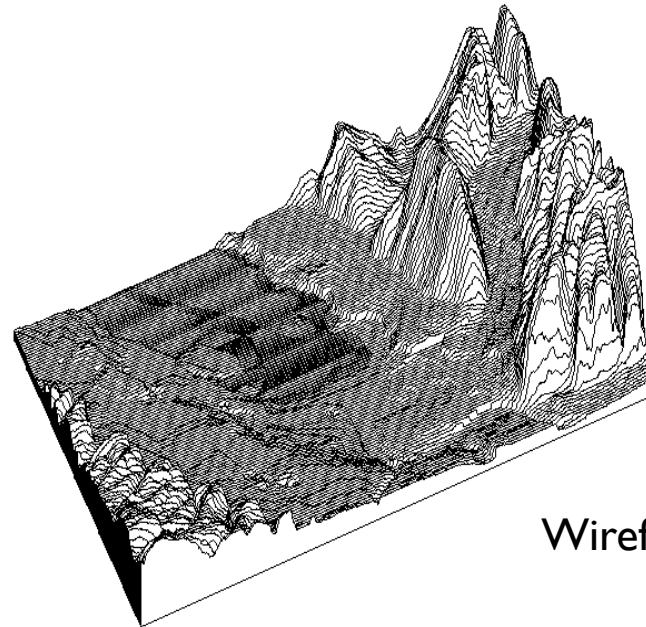
elevation as grey value



Grayscale



profile



Wireframe

# Calibrating

Si map  
Si map ♦  
Si map ♦♦

◆ un-scaled (scaled to pixel)  
◆ scaled  
◆◇ scaled and calibrated

	Measured	Known
1	20.10	98
2	249.12	2
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

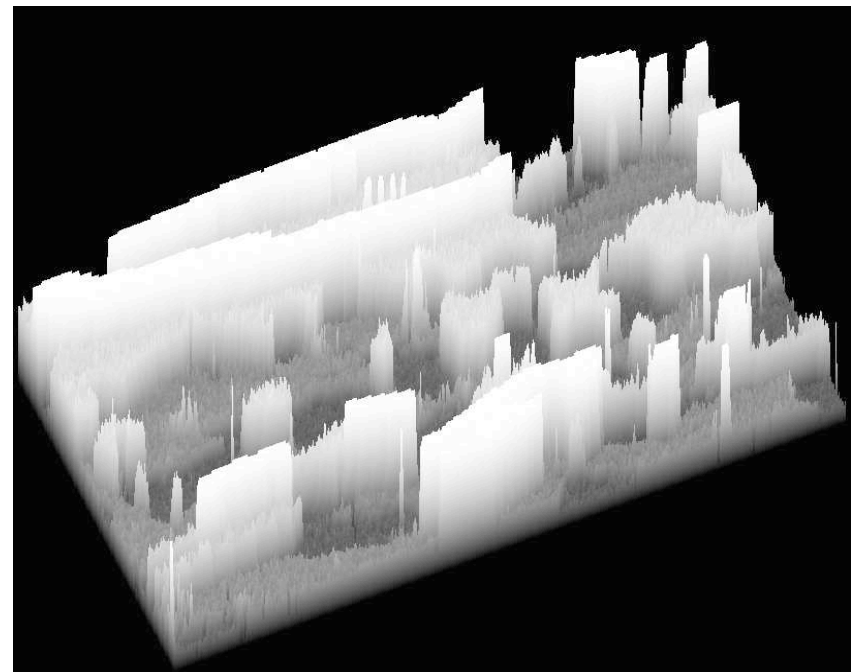
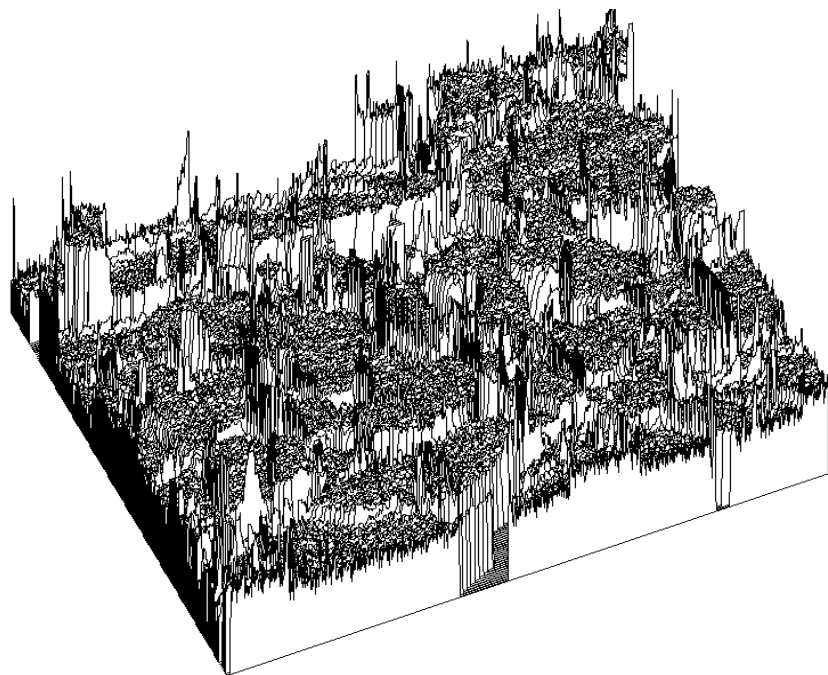
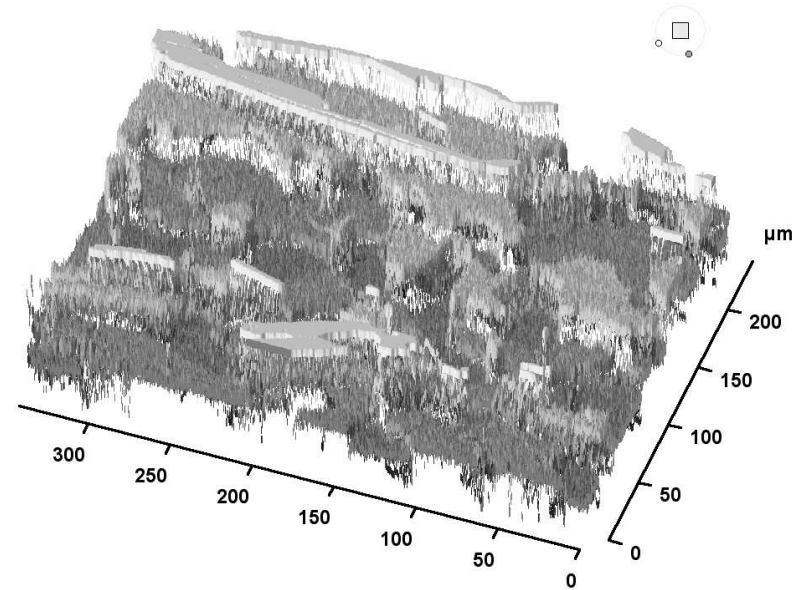
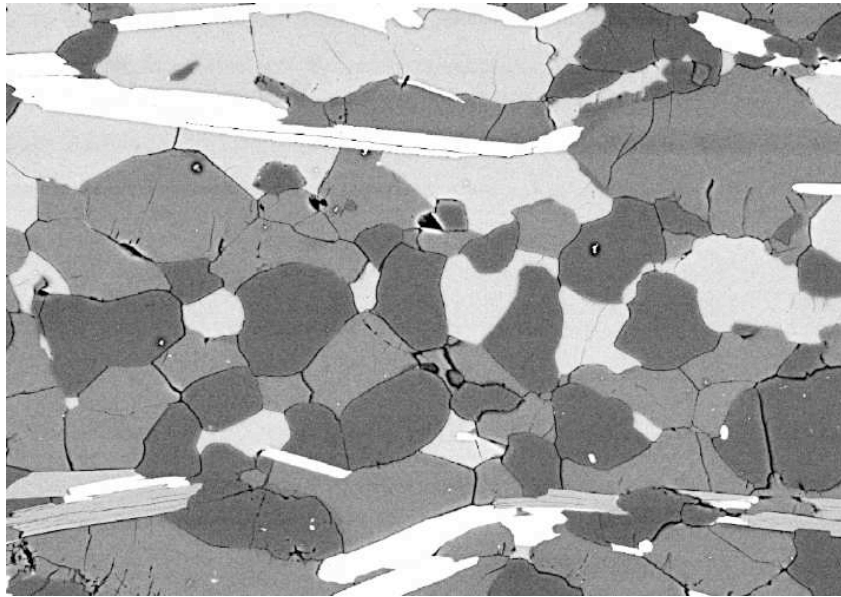
Straight Line  
 2nd Degree Polynomial  
 3rd Degree Polynomial  
 4th Degree Polynomial  
 Exponential  
 Power  
 Log  
 Rodbard  
 Uncalibrated OD  
 Uncalibrated

Unit of Measure: %

Save... Open... Invert OD

Cancel OK

# Visualization of image topography



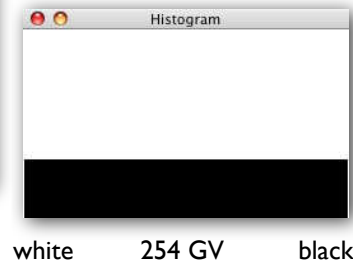
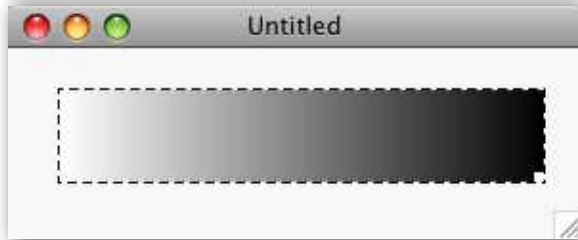


# Making a grey scale

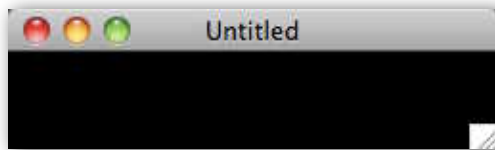
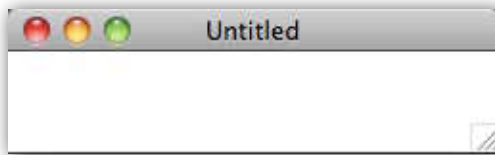
1, 2



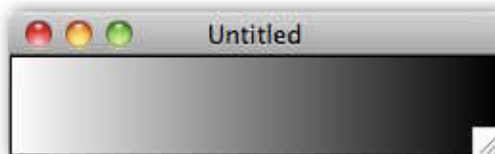
3



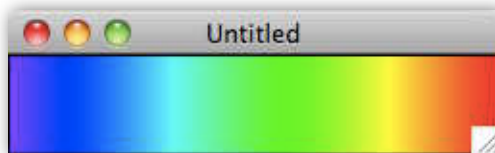
4



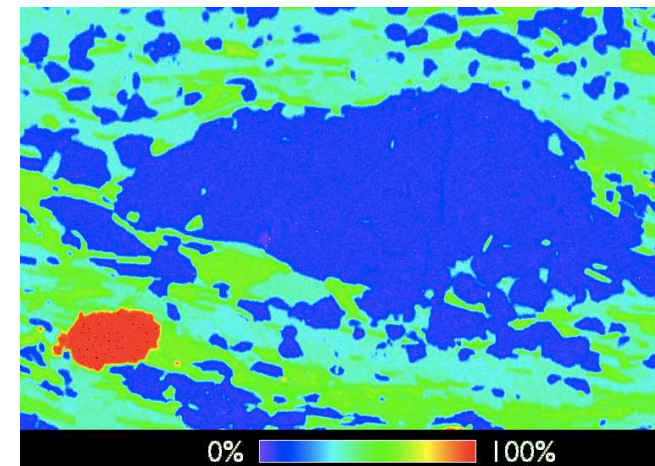
5



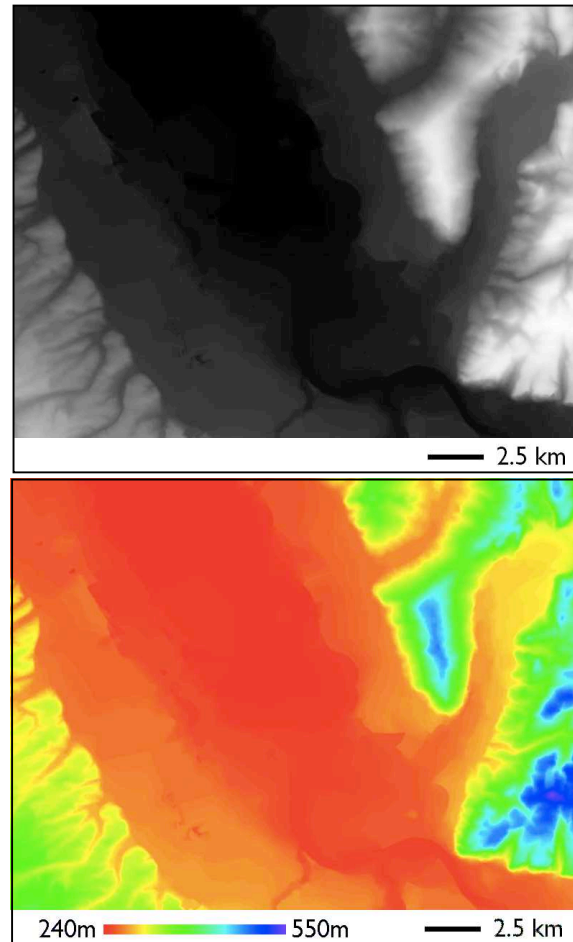
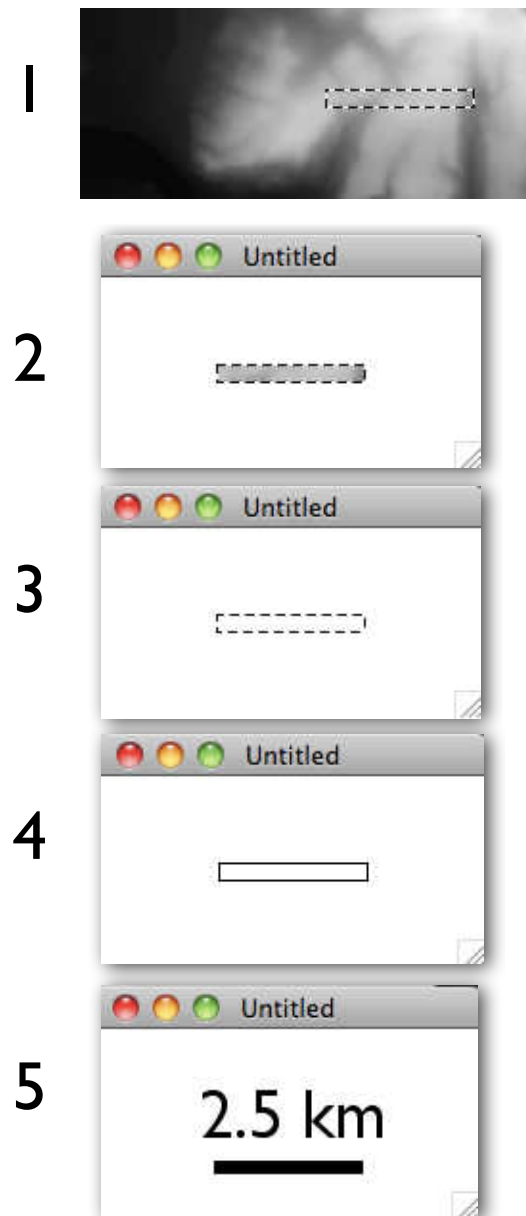
6



1. make new file using 'New' command ( $\text{⌘}N$ ) in File menu;
2. select region of interest (ROI), size  $254 \cdot 50$ ;
3. create grayscale using 'Draw Scale' command in Edit menu;
4. optional for boundary: make new file of  $256 \cdot 52$ , fill black for black boundary, leave white for white boundary;
5. paste grayscale into new file
6. paste grayscale into image (element map from Figure 3.18) or propagate LUT from image to grayscale.



# Making a scale bar



1. select region of interest (ROI) of known true width (map from Figure 3.18.e); copy (⌘C);
2. create new file (⌘N); paste scale (⌘V);
3. with selection still active; clear ROI and draw boundary using delete key and 'Draw Boundary' command in Edit menu;
4. fill, using Paint Bucket tool (7, Figure 3.14);
5. label (use sans-serif font, e.g., Gill Sans)
6. copy (⌘C) and paste (⌘V) into image (top); same with color LUT and calibration added (as in Figure 3.20) (bottom).



# Übung I - Monochrome Bilder (b/w)

Bilder als Datenmatrizen begreifen, den Datenumfang erkennen.

- Ein paar Bilder (z.B. Truzzo.tif, SEMsymplectite.tif) öffnen.

Wie gross (Breite, Höhe) sind sie? (Einheiten?)

Wieviel Speicherplatz brauchen sie? (Einheiten?)

Wie gross ist ihr Kontrast- bzw. Grauwertumfang?

(min./max., Grauwert, Mittelwert, Standardabweichung)

Was bedeutet ein grosser/kleiner Grauwertumfang?

Bilder als Karten begreifen, (Grau-)werte interpretieren.

- Bild (Blatt\_1047.tif) öffnen.

Was bedeuten die Grauwerte? Was bedeutet das Histogramm?

Profile legen - Surface Plot herstellen. Was sieht man?

Skalierte und kalibrierte Bilder.

- Bildpaar (1047\_scal.tif & 1047\_nonscal.tif) öffnen.

Was unterscheidet die scheinbar gleichen Bilder? -

Kalibrieren und skalieren Sie 1047\_nonscal.tif.

Beauty case.

- Skaliertes und kalibriertes Bild öffnen.

Masstab und Grau- / Farbskala herstellen und einfügen

# Fiji - imageJ (Java)

can be used with Mac and PC:

<http://fiji.sc/wiki/index.php/Fiji>

The image shows a screenshot of the Fiji website with several software windows overlaid. The website content includes:

- Navigation menu: Navigation, Content, Highlights, Toolbox, Login
- Post title: **Fiji Is Just ImageJ** (+1, 60)
- Post content:
  - short URL
  - Fiji is an image processing package. It can be described as a distribution of ImageJ (and soon ImageJ2) together with Java, Java 3D and a lot of plugins organized into a coherent menu structure. Fiji compares to ImageJ as Ubuntu compares to Linux.
  - The main focus of Fiji is to assist research in life sciences. (This sentence is circled in red in the original image.)
  - For users, Fiji is easy to install and has an automatic update function, bundles a lot of plugins and offers comprehensive documentation.
  - For developers, Fiji is an open source project hosted in a Git version control repository, with access to the source code of all internals, libraries and plugins, and eases the development and scripting of plugins.
- Buttons: Like (164), Send, Tweet (23), Download Fiji now
- News section:
  - 2012-05-10 - New plugin: TrackMate
  - 2012-04-18 - New Plugin: Bleach Correction
  - 2012-04-09 - First beta of ImageJ2 is out
  - 2012-04-01 - Fiji release of the Balloon Plugin
  - 2012-01-19 - New Release of Stitching
- Collaboration section:
  - The Fiji project is driven by a strong desire to improve the available for life sciences to process and analyze data. To end, Fiji collaborates closely with the following projects:
  - Logos for ImageJ2, Bio-Formats, OME, µManager, and KNIME.

Overlaid software windows:

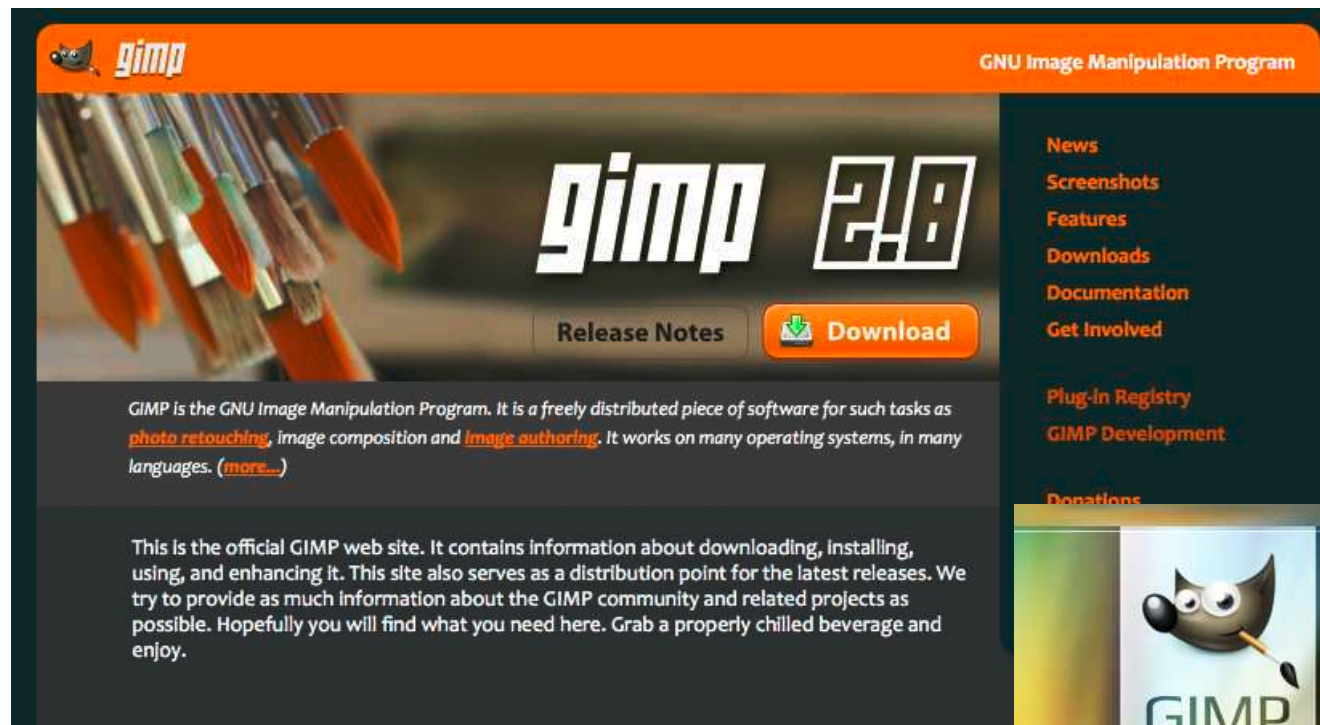
- Fiji** window: Shows a toolbar with various tools like Polygon selections, selection tools, and navigation tools.
- Up-to-date check** dialog: "There are updates available. Do you want to start the Fiji Updater now?" Buttons: Remind me later, Never, Yes, please.
- Information** dialog: "Updated successfully. Please restart Fiji!" Button: OK.



# gimp - GNU image manipulation program

can be used with Mac and PC:

<http://www.gimp.org/>



GIMP is the GNU Image Manipulation Program. It is a freely distributed piece of software for such tasks as photo retouching, image composition and image authoring. It works on many operating systems, in many languages.

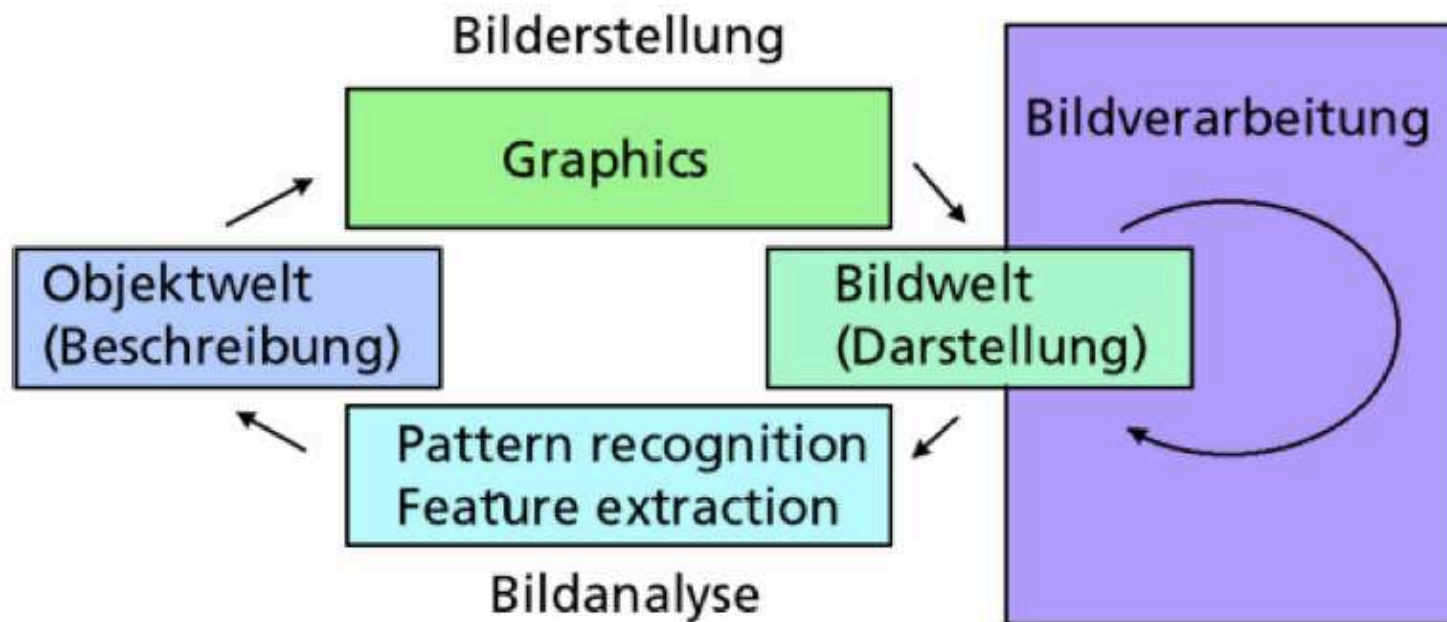


# Bildanalyse



# Bildanalyse versus Computergrafik

Bildverarbeitung	Bild	→ Bild
Bildanalyse	Bild	→ Zahl / Objekt
Computergraphik	Zahl / Objekt	→ Bild



# Bildanalyse versus Bildverarbeitung

Bild → Bild

image processing

image in

image out

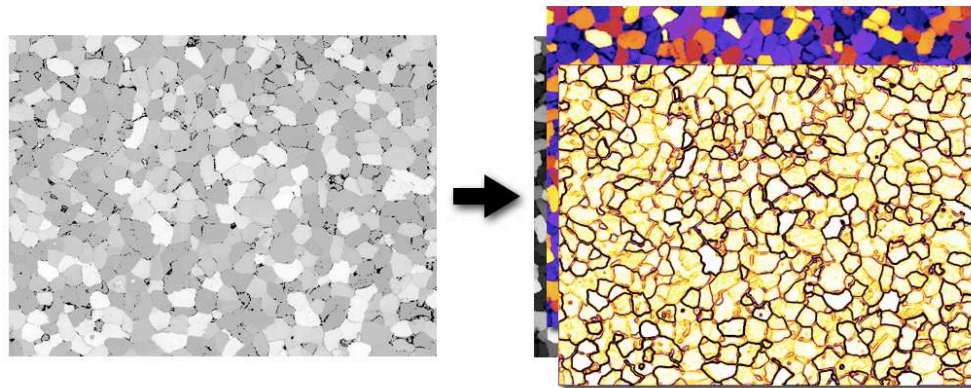
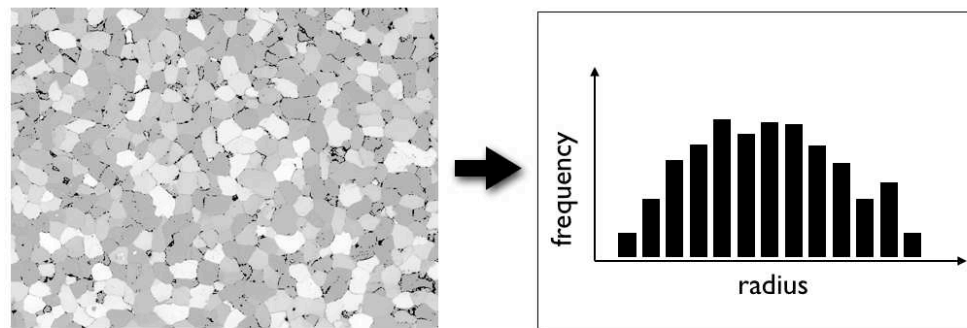


Bild → Zahl

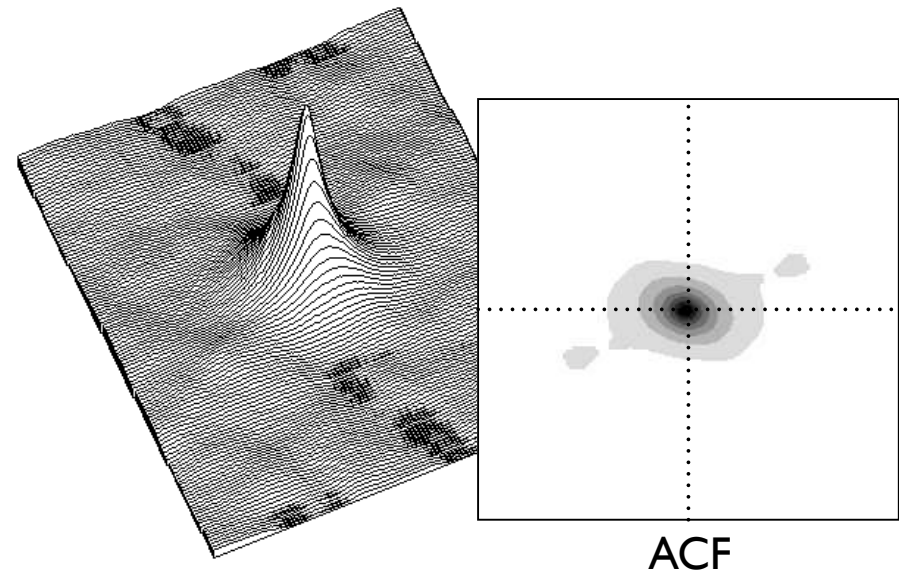
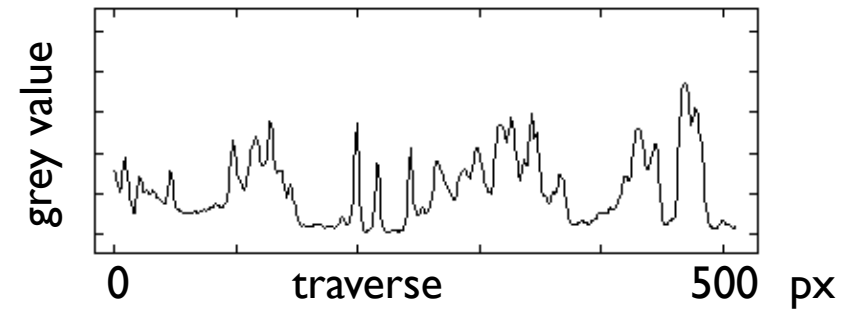
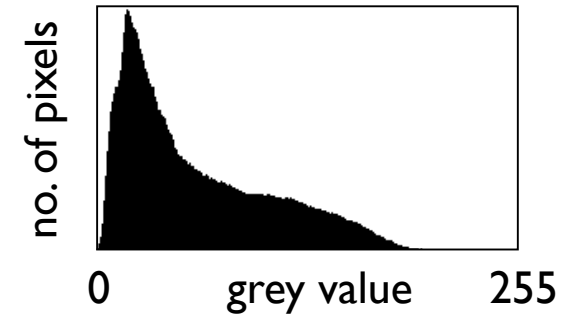
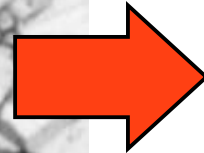
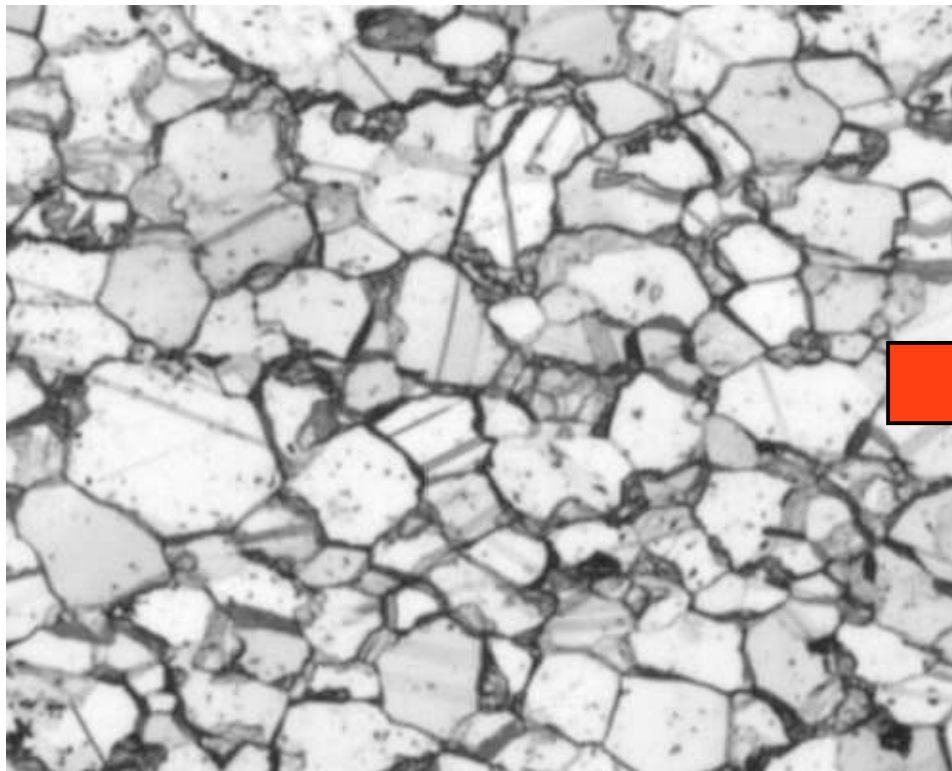
image analysis

image in

number out

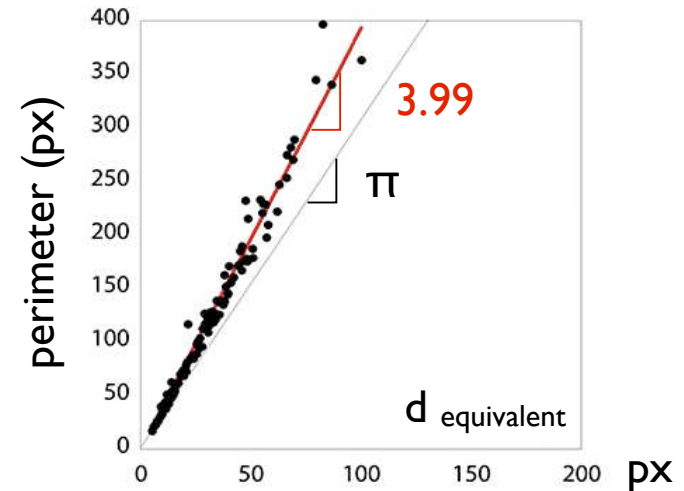
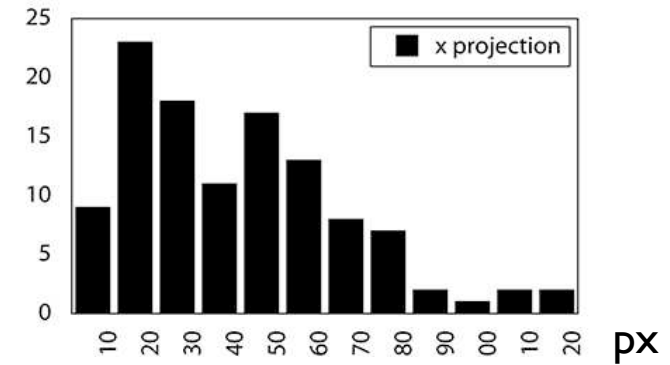
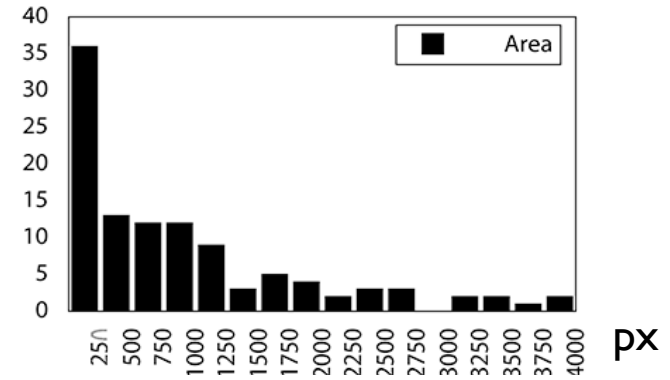
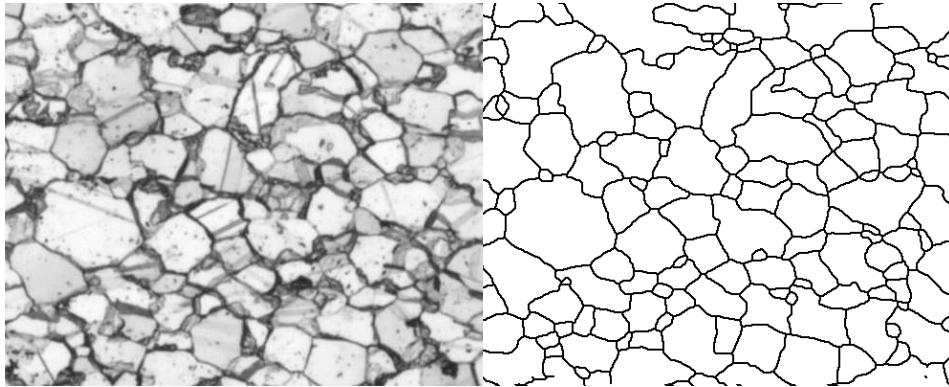


# Typ I: Direkte Bildanalyse

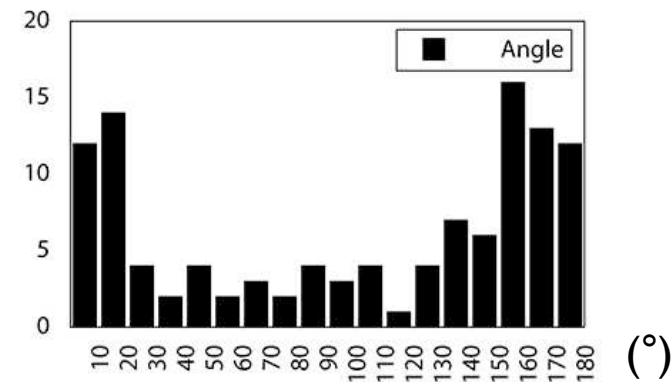
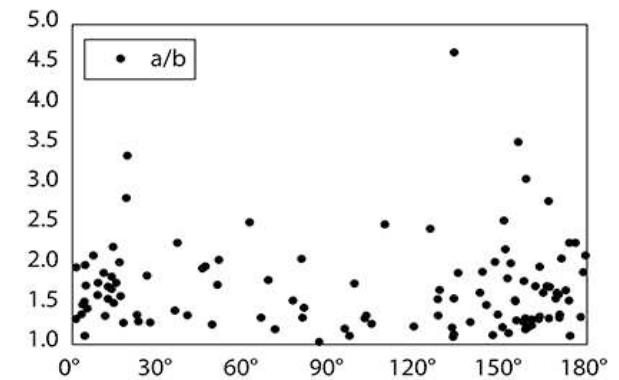
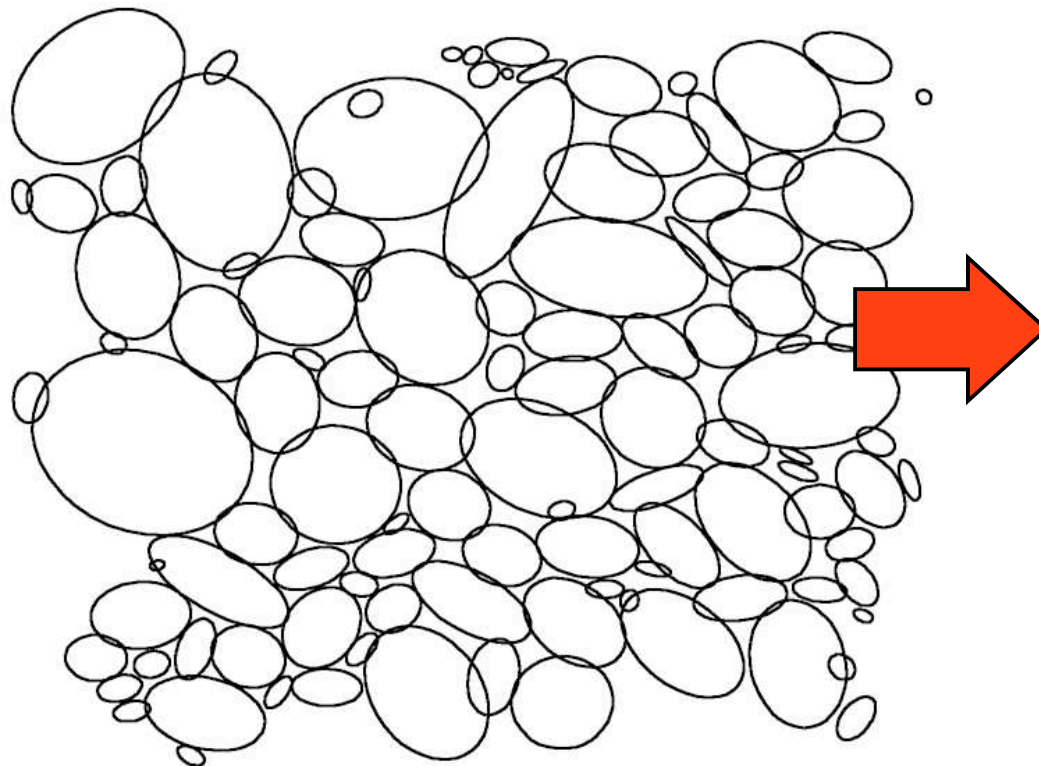
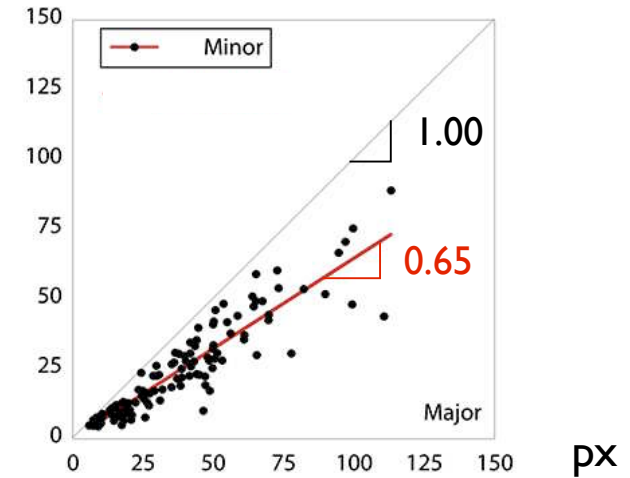
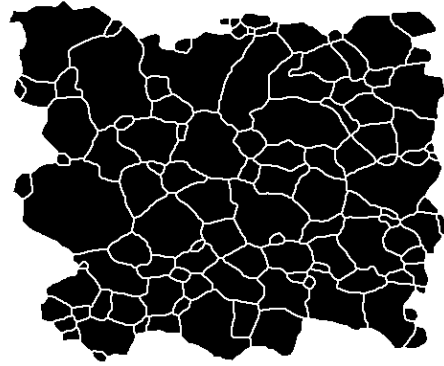
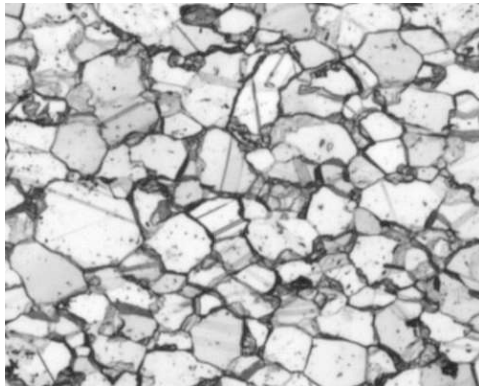




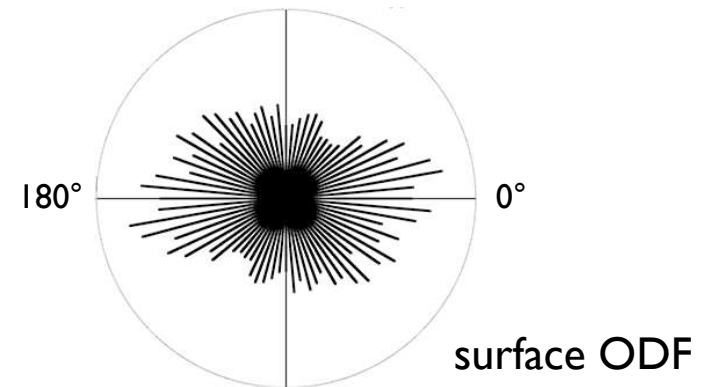
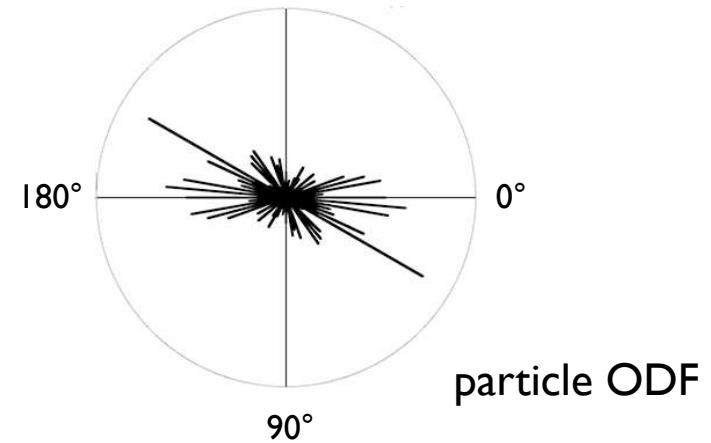
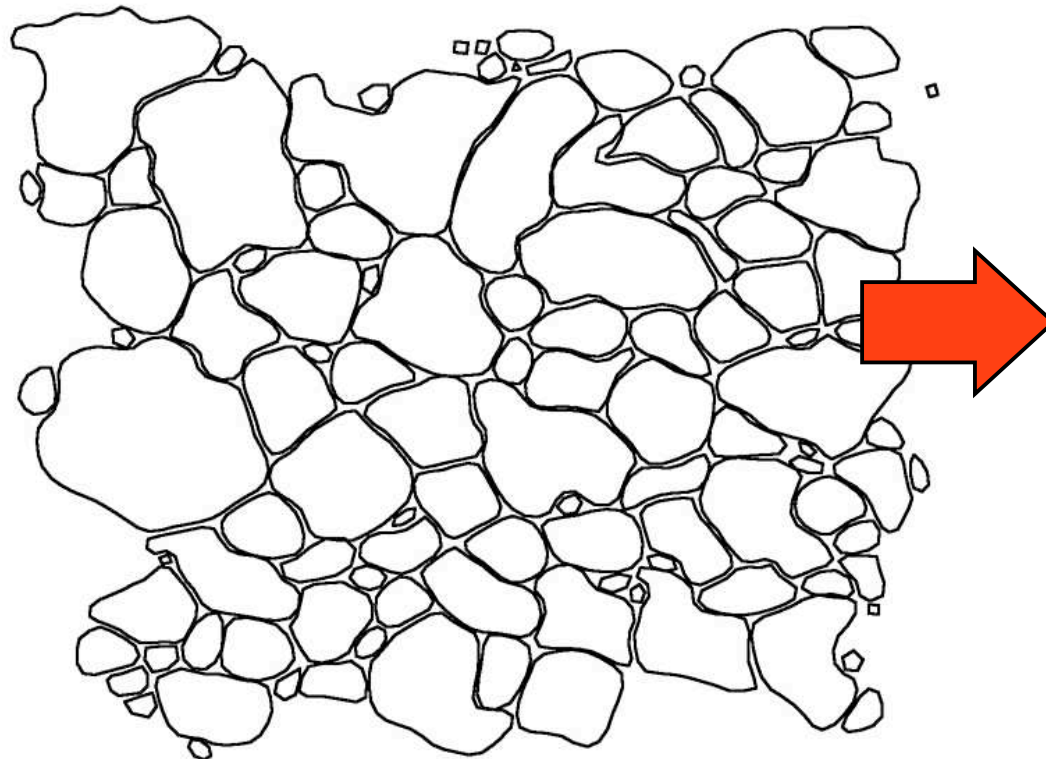
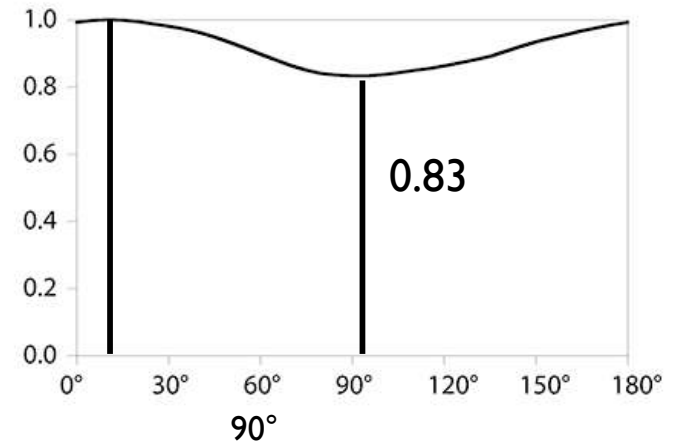
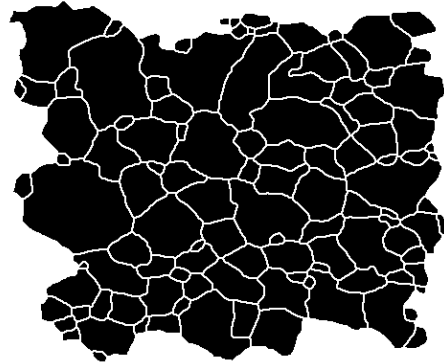
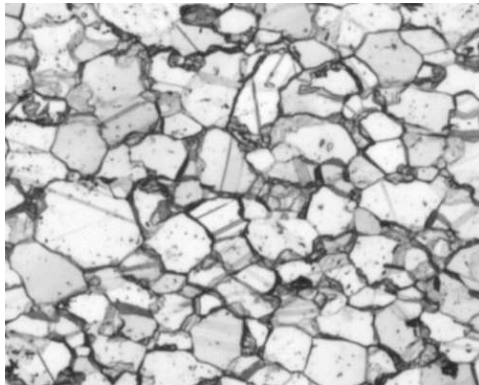
# Typ 2: Analyse von Segmenten



# Typ 3: Analyse von best-fit Ellipsen



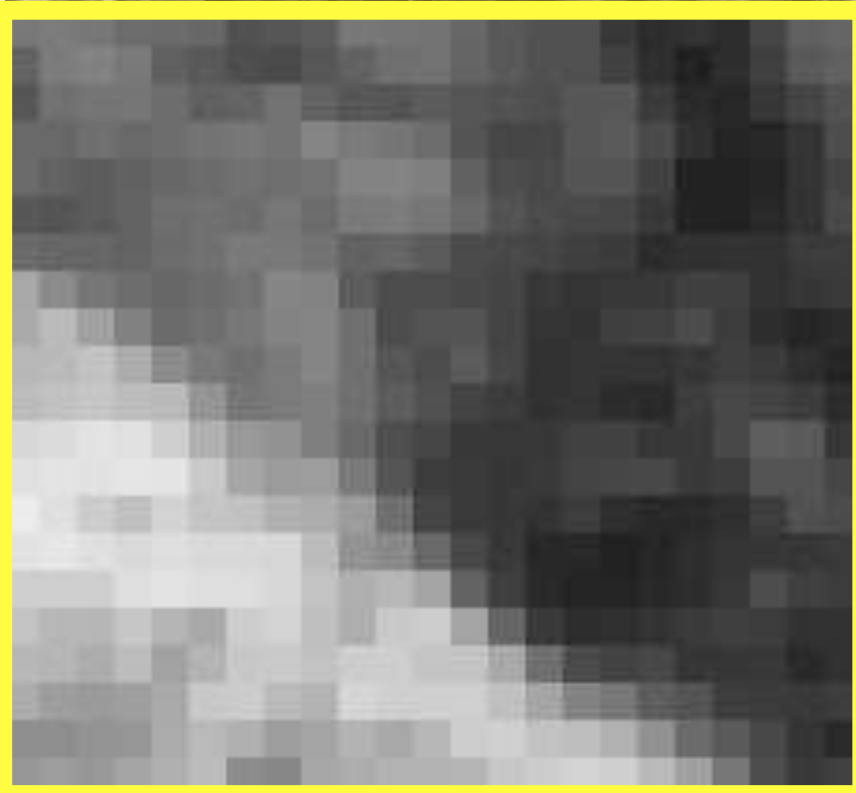
# Typ 4: Analyse von Konturen





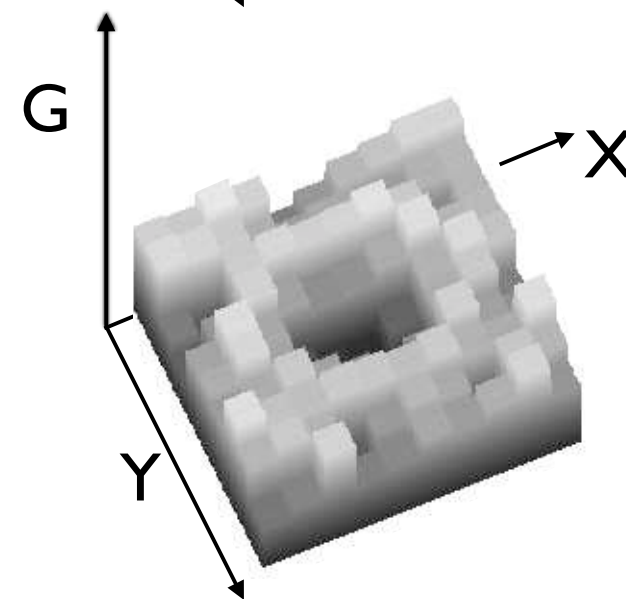
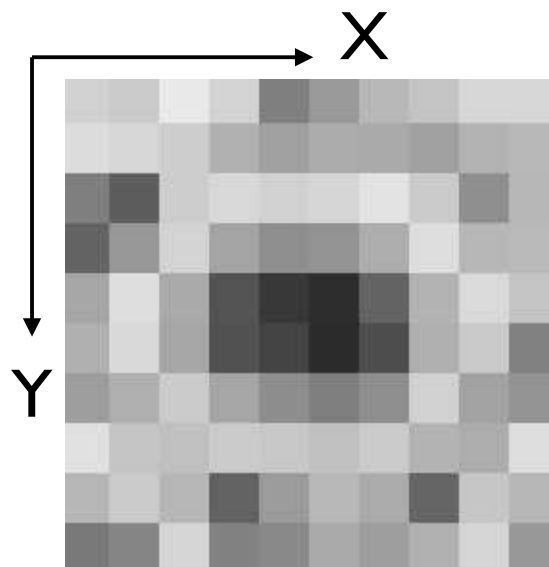
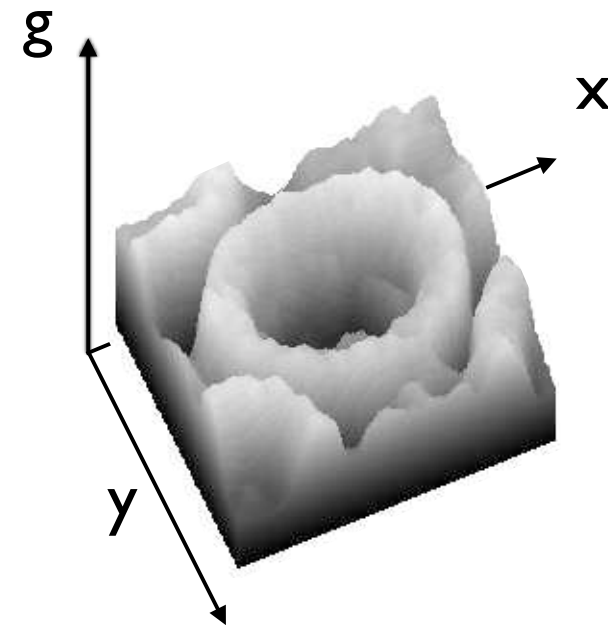
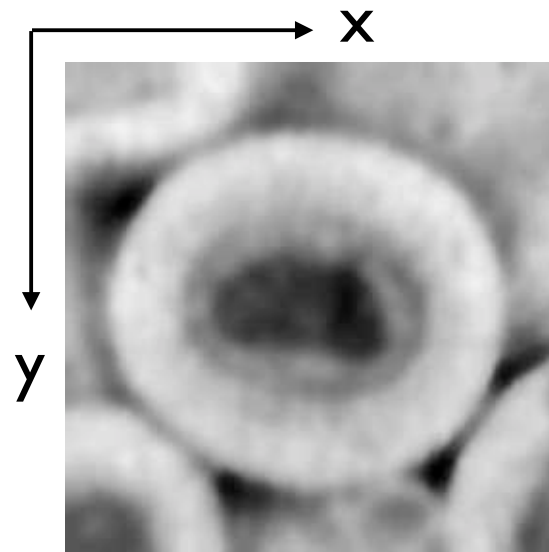
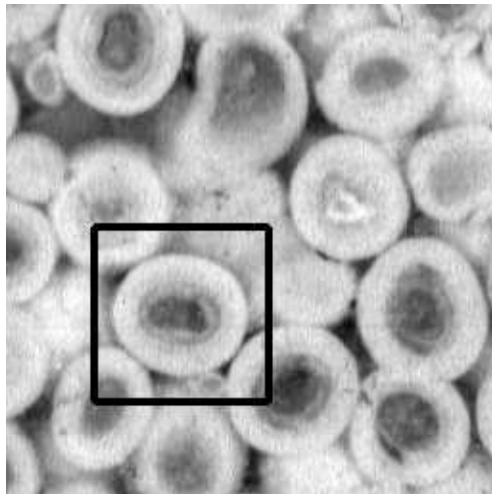
# digitale Bilder

# das digitale Bild



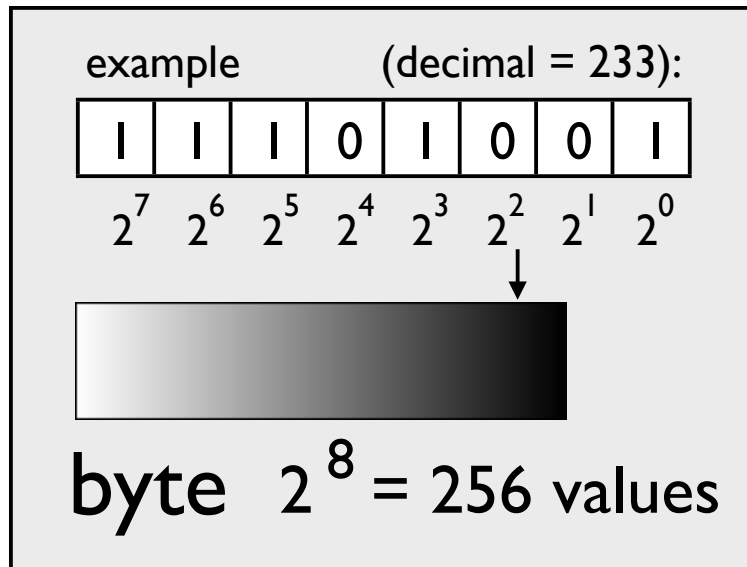
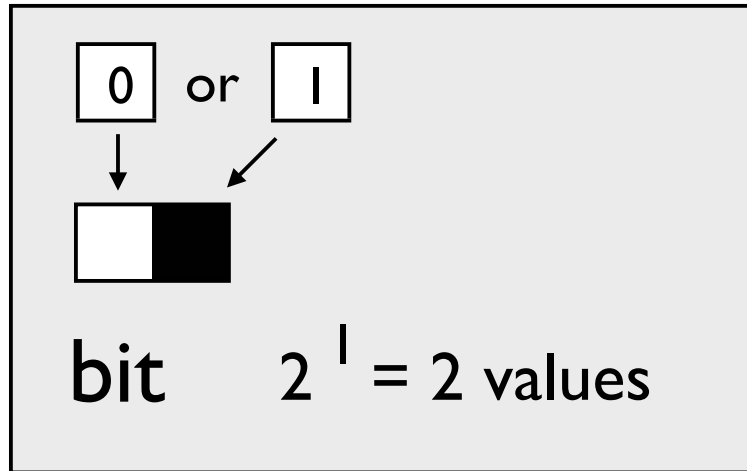
```
134 131 135 146 148 151 173 168 161 135 137 139 152 167 173 174 198
155 131 124 133 158 165 176 180 168 156 143 141 154 165 172 175 188
168 142 138 137 145 158 155 141 157 167 169 161 169 172 176 168 167
150 151 143 149 145 139 135 139 122 132 137 146 171 184 184 168 164
148 157 162 157 151 147 141 144 140 123 123 128 157 178 181 171 170
167 169 164 156 145 143 146 137 146 132 130 137 150 171 180 181 184
148 152 152 155 147 141 132 134 140 157 153 163 179 181 185 191 195
87 116 136 146 151 146 140 121 124 162 178 177 181 185 198 202 199
85 69 94 126 148 143 135 124 121 144 178 171 171 186 202 203 191
71 69 60 82 116 133 142 132 121 142 169 177 164 184 205 202 203
67 61 57 65 70 107 136 133 127 142 162 174 186 195 205 203 209
40 36 28 31 48 78 102 109 127 149 176 185 198 200 198 190 189
31 28 30 26 27 54 88 100 98 132 169 193 196 199 197 187 185
18 31 50 62 43 58 61 78 82 99 143 186 196 199 203 195 208
28 25 31 37 32 38 38 39 67 108 117 150 182 198 215 213 221
48 49 48 34 28 33 33 40 61 79 71 90 156 192 212 218 217
61 72 72 57 75 86 50 44 64 81 54 50 91 153 197 209 207
71 73 81 67 92 75 54 53 61 50 49 58 59 86 144 179 187
82 97 101 96 85 54 51 68 75 42 47 47 48 63 89 124 136
112 113 107 105 84 70 78 98 90 76 86 72 51 47 61 65 78
105 98 103 91 80 68 114 120 89 82 76 76 74 56 50 43 48
```

# analog - digital Diskretisierung





# Bits and bytes $2^8 = 256$



pixel = picture element

bit or byte

1 bit image:

bitmap

8 bit (byte) image:

greyscale

monochrome

Abbreviations:

bit

b

byte

B, kB, MB, GB



# Number systems and ASCII code

decimal	binary	octal	hexadecimal	ASCII
0	00000000	000	00	NUL
127	01111111	177	7F	DEL
255	11111111	377	FF	ÿ
65	01000001	101	41	A
97	01100001	141	61	a
13	00001101	015	0D	CR
10	00001010	012	0A	LF

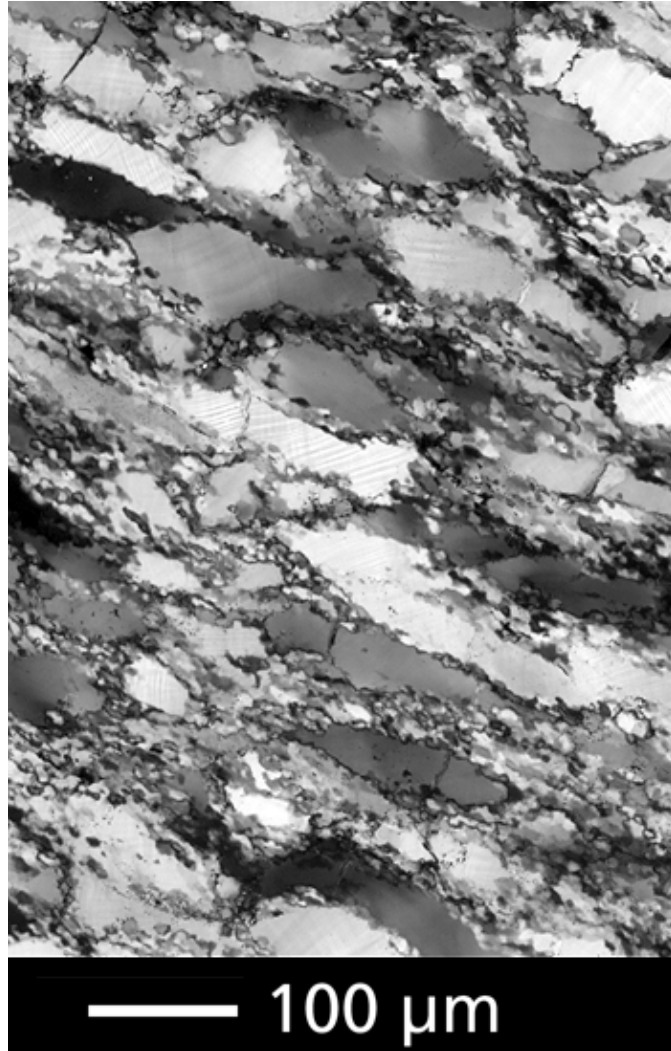
# Digital size of 1500 · 1000 image

size = n (channels) · X · Y (dimension) · depth (bit/px)

type	bit	byte	kB (1024 byte)	MB (1024 kB)
bitmap (1 bit / pixel)	1,500,000	187,500	183.1	0.179
grayscale (1 byte / pixel)	12,000,000	1,500,000	1464.8	1.431
grayscale (16 bit / pixel)	24,000,000	3,000,000	2929.7	2.810
<b>RGB colour (24 bit / pixel)</b>	36,000,000	4,500,000	4394.5	4.292



# Vergrößerung



Vergrößerung

$$m = \frac{\text{Bildgrösse}}{\text{Objektgrösse}}$$

Bildgrösse: Grösse des Objekts im Bild  
(Abbildungsgrösse)

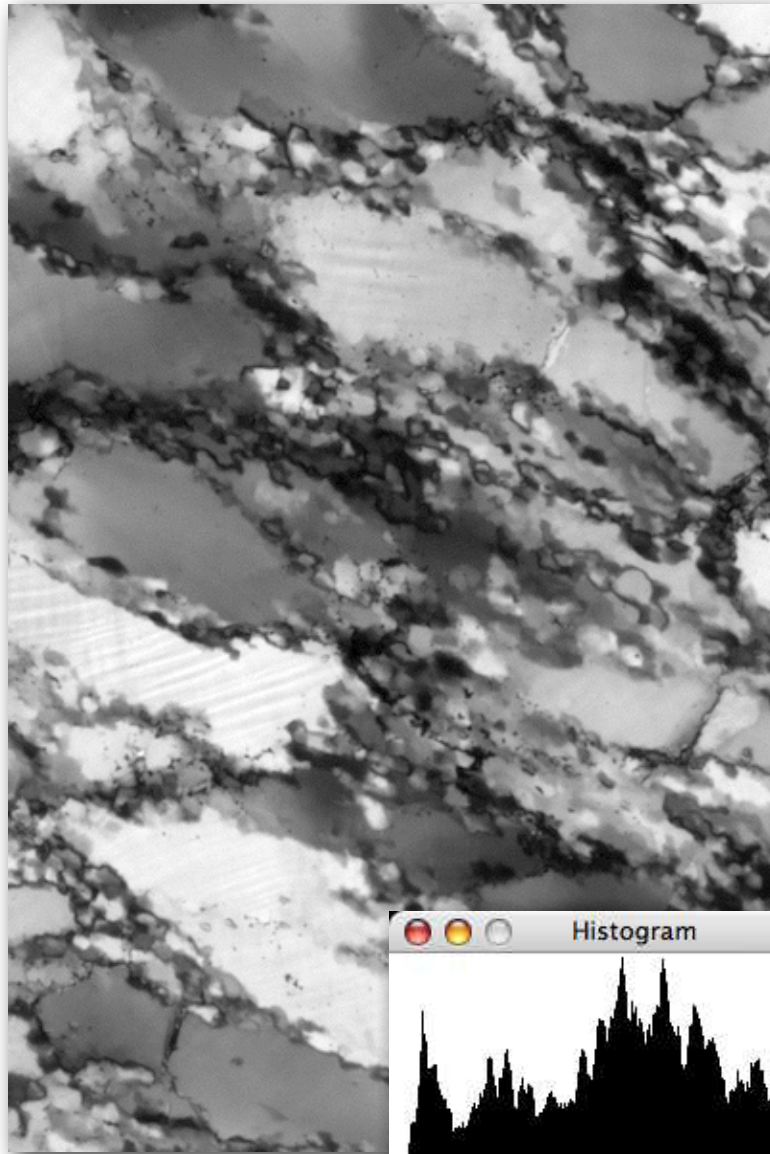
≠ Grösse des Bildes in Pixel

≠ Grösse des Bildes in cm

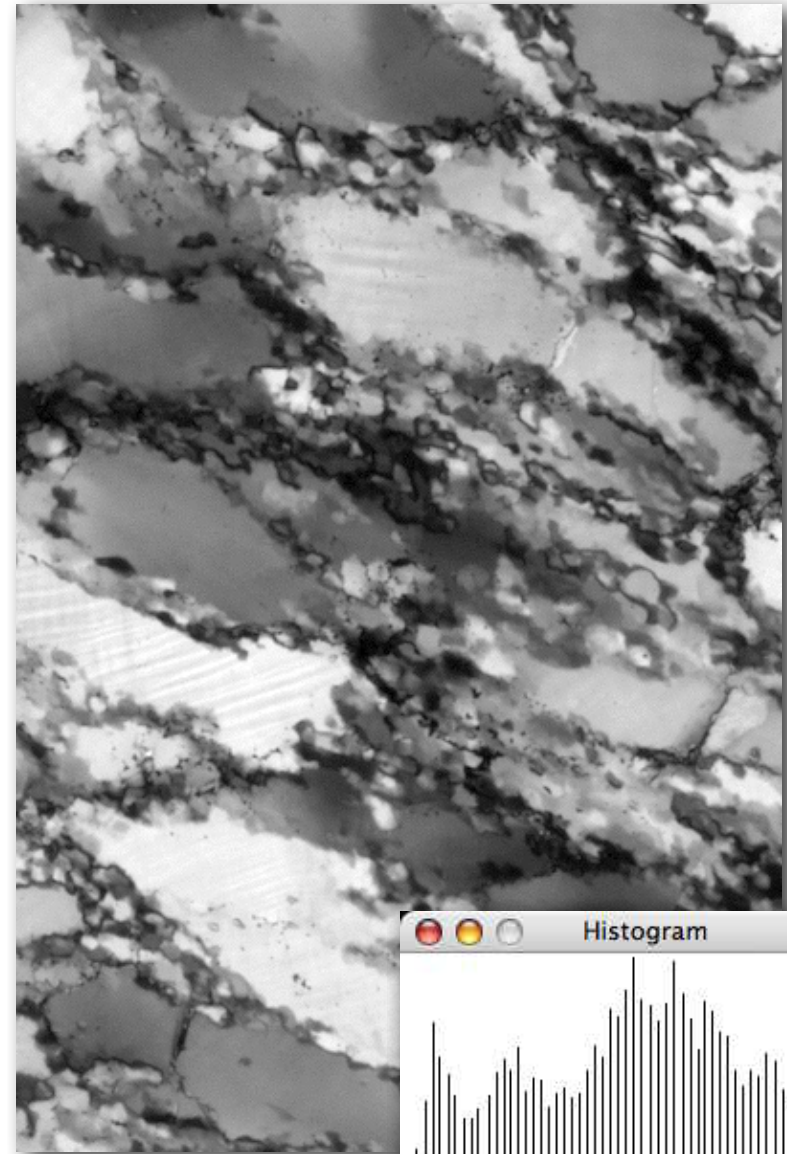
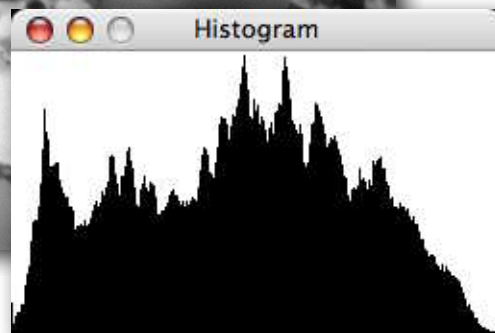
Massstab enkopieren

# Grauwerte

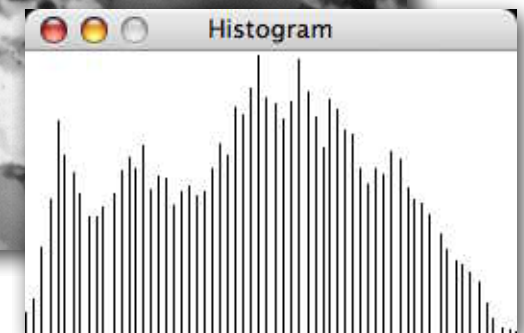
# Dynamische Auflösung



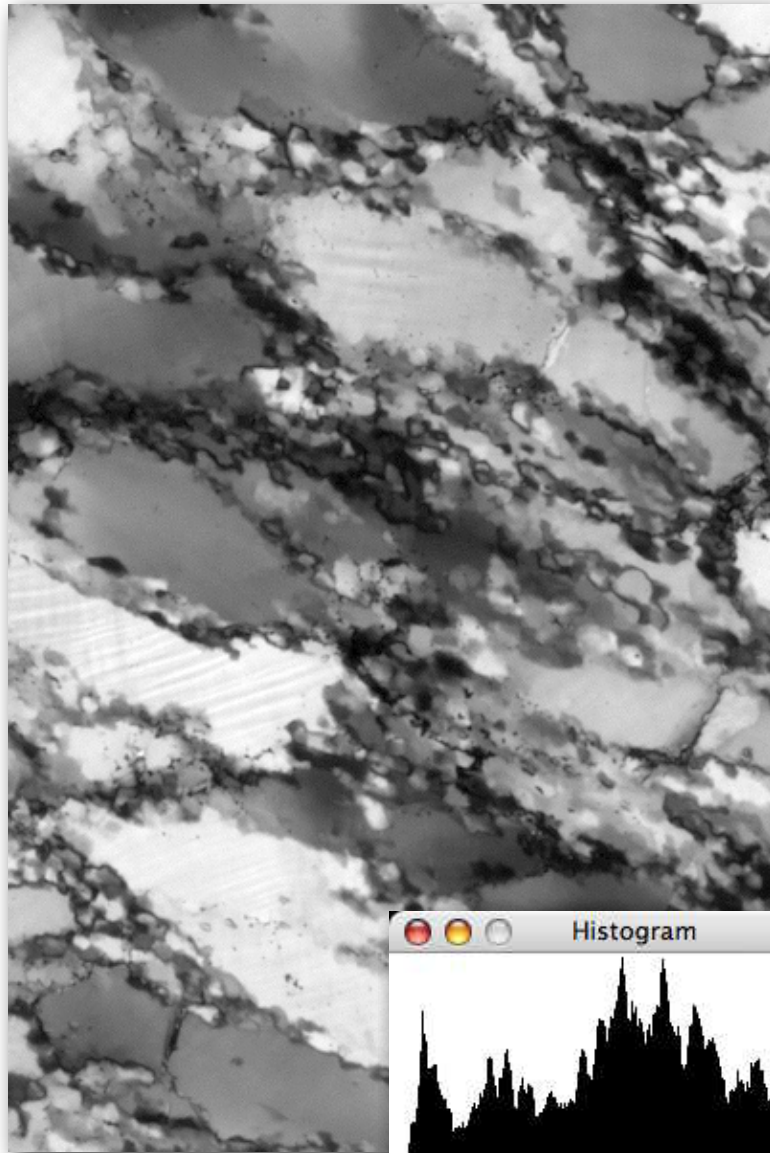
8 bit / pixel



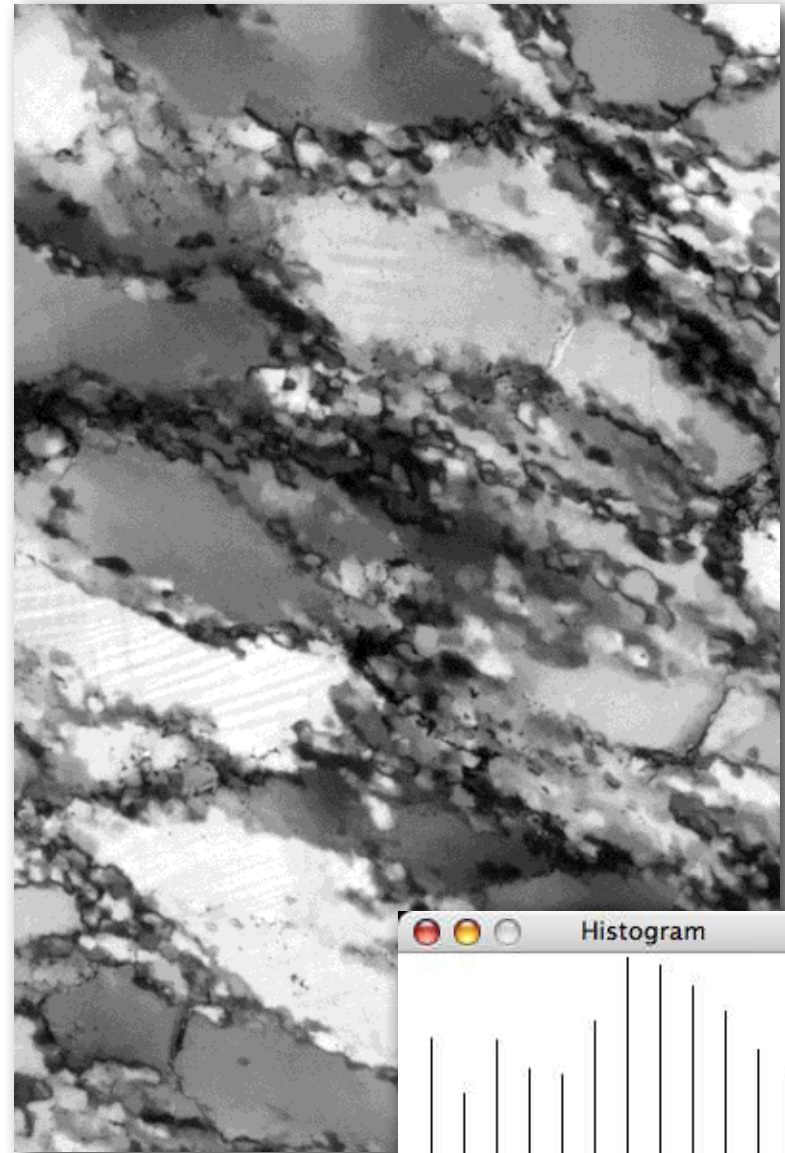
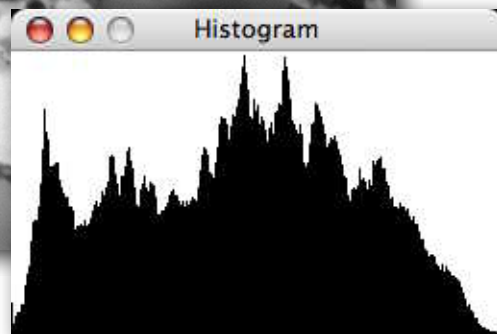
6 bit / pixel



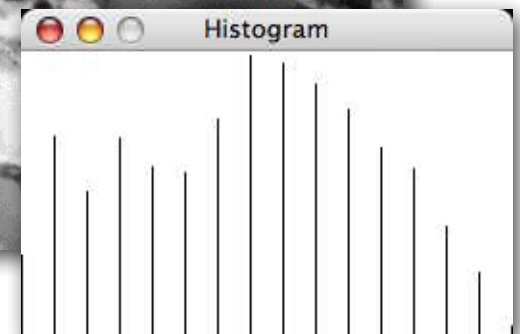


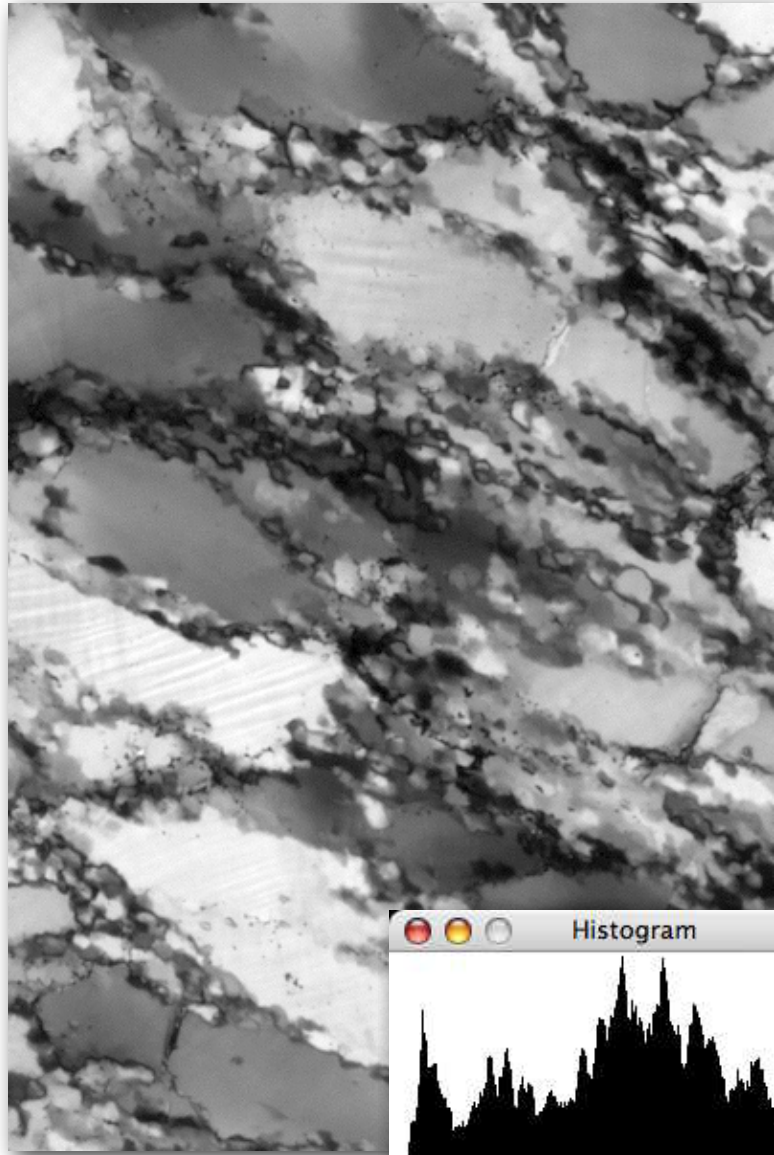


8 bit / pixel

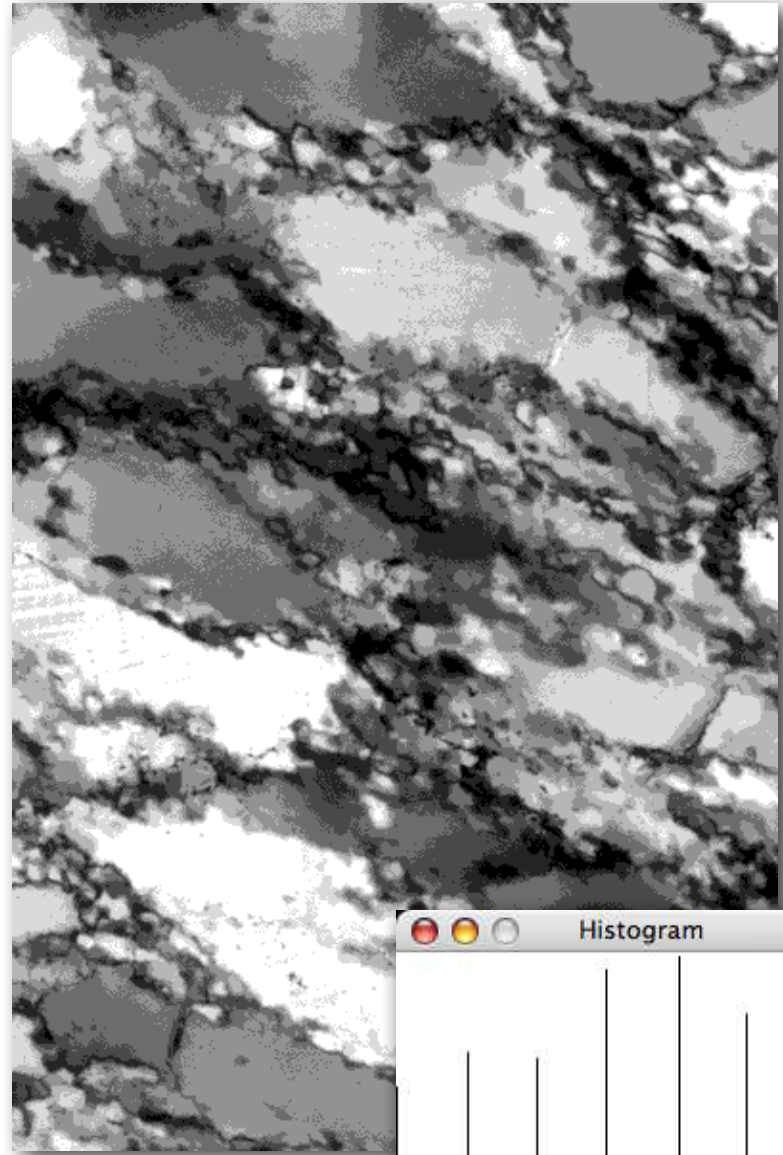
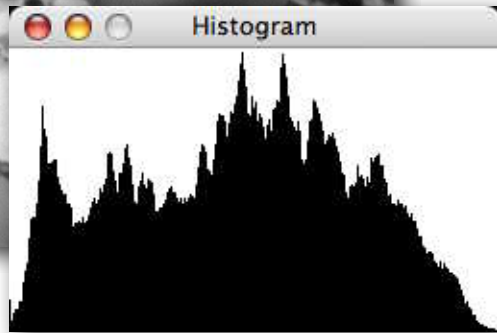


4 bit / pixel

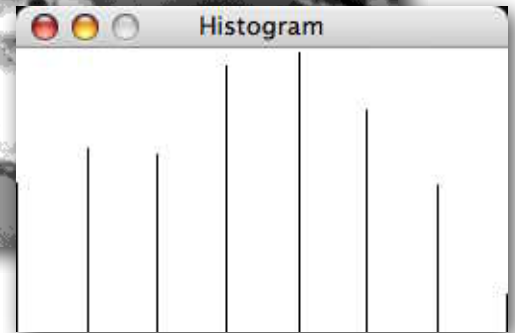


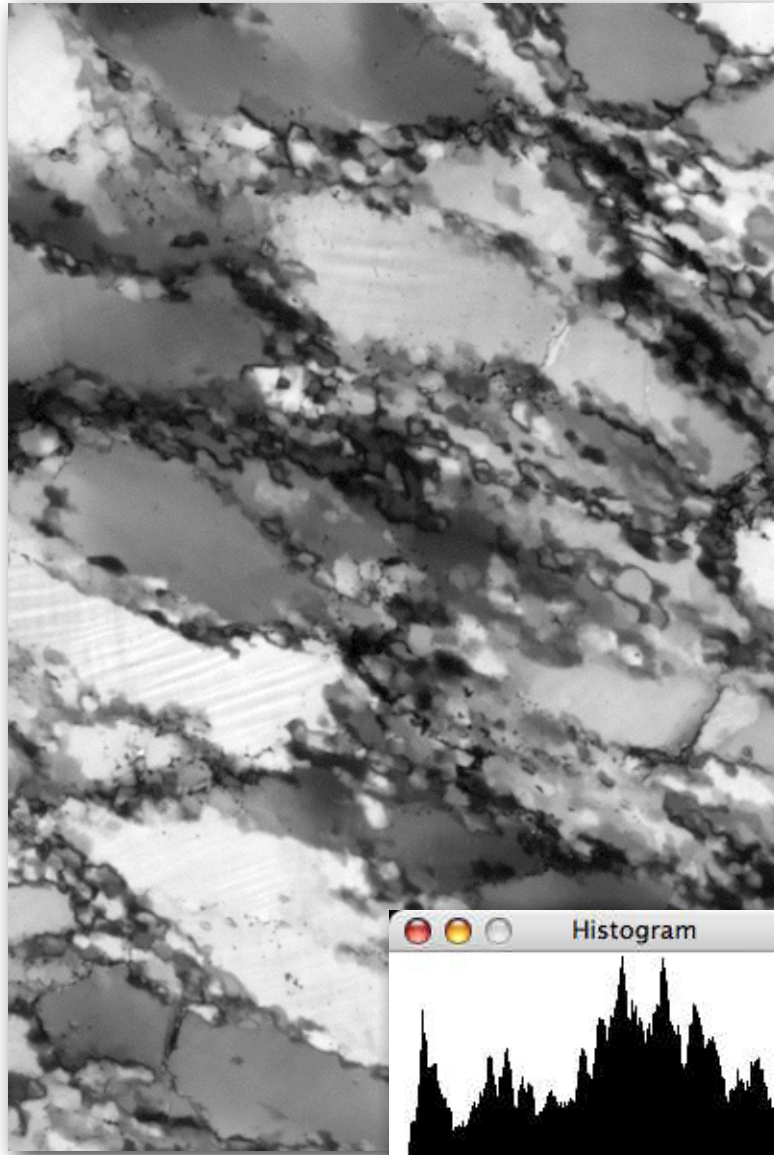


8 bit / pixel

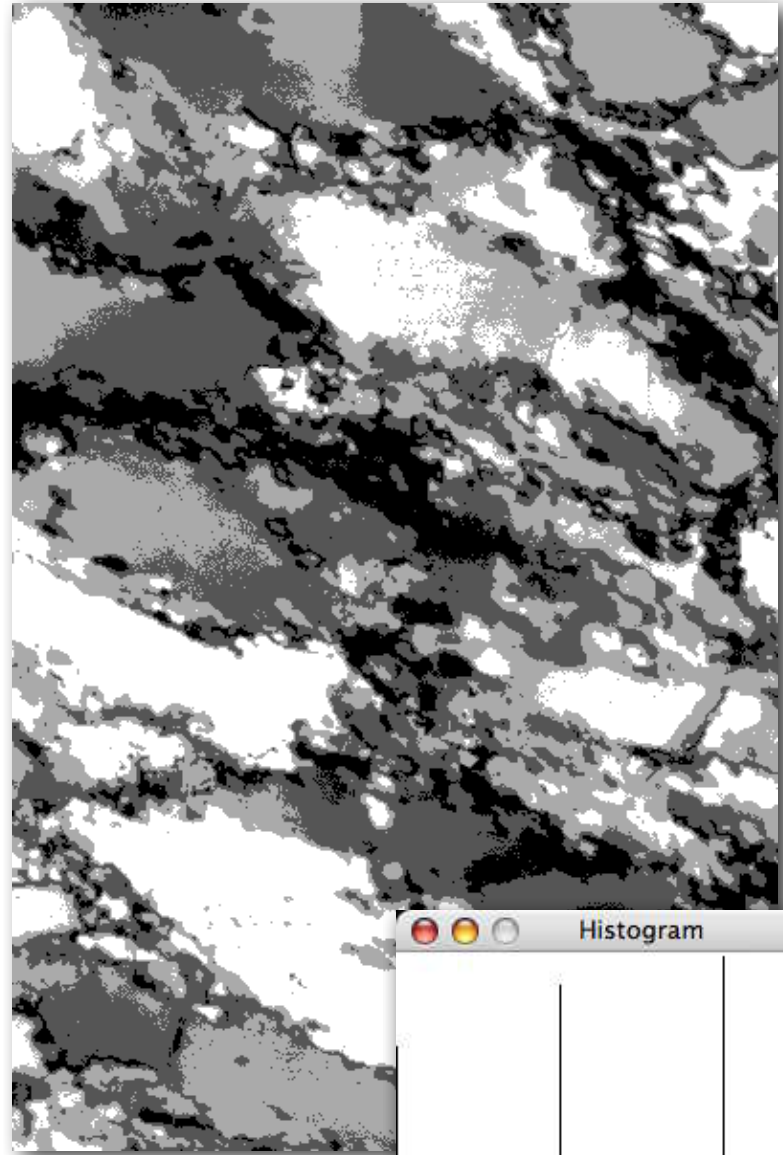
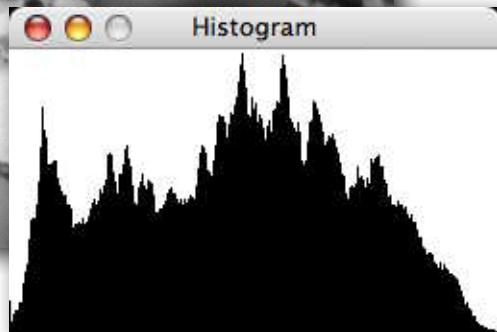


3 bit / pixel

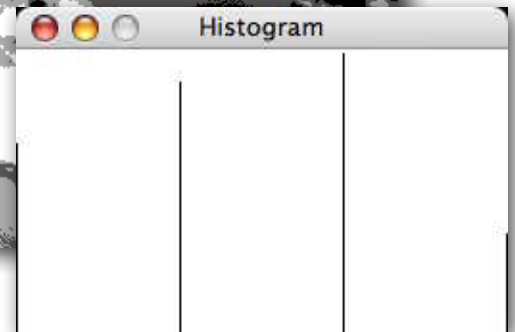




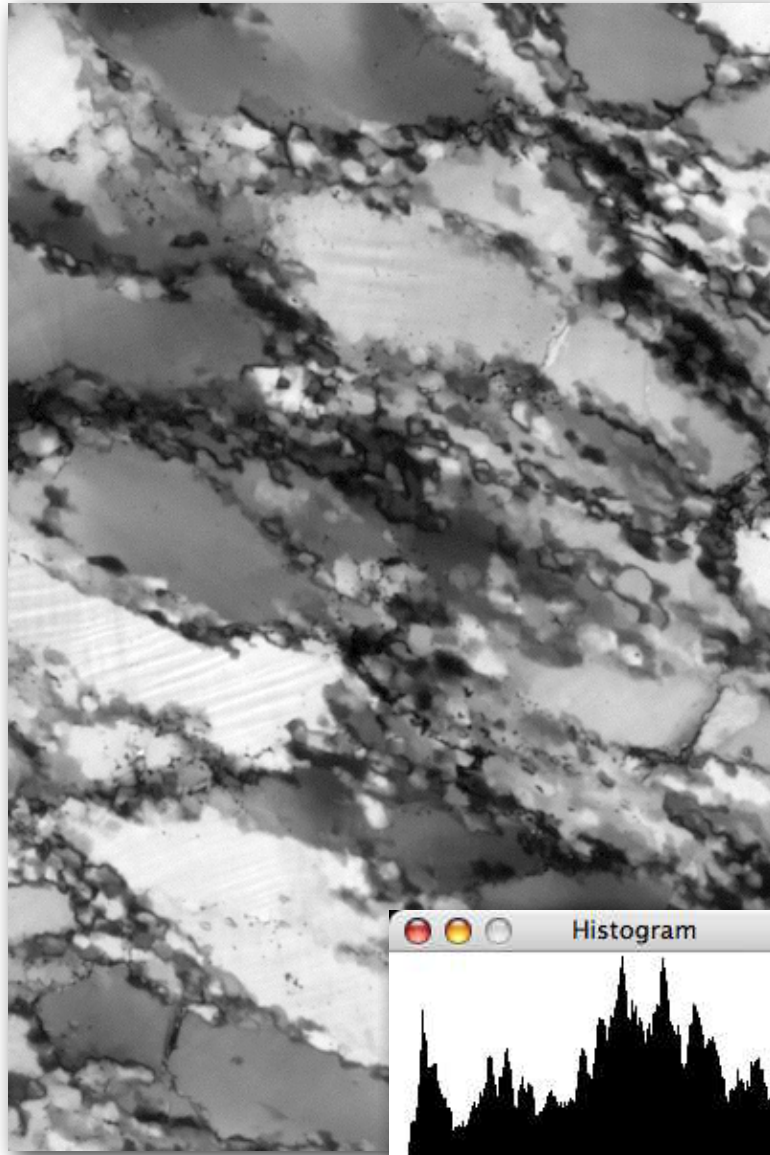
8 bit / pixel



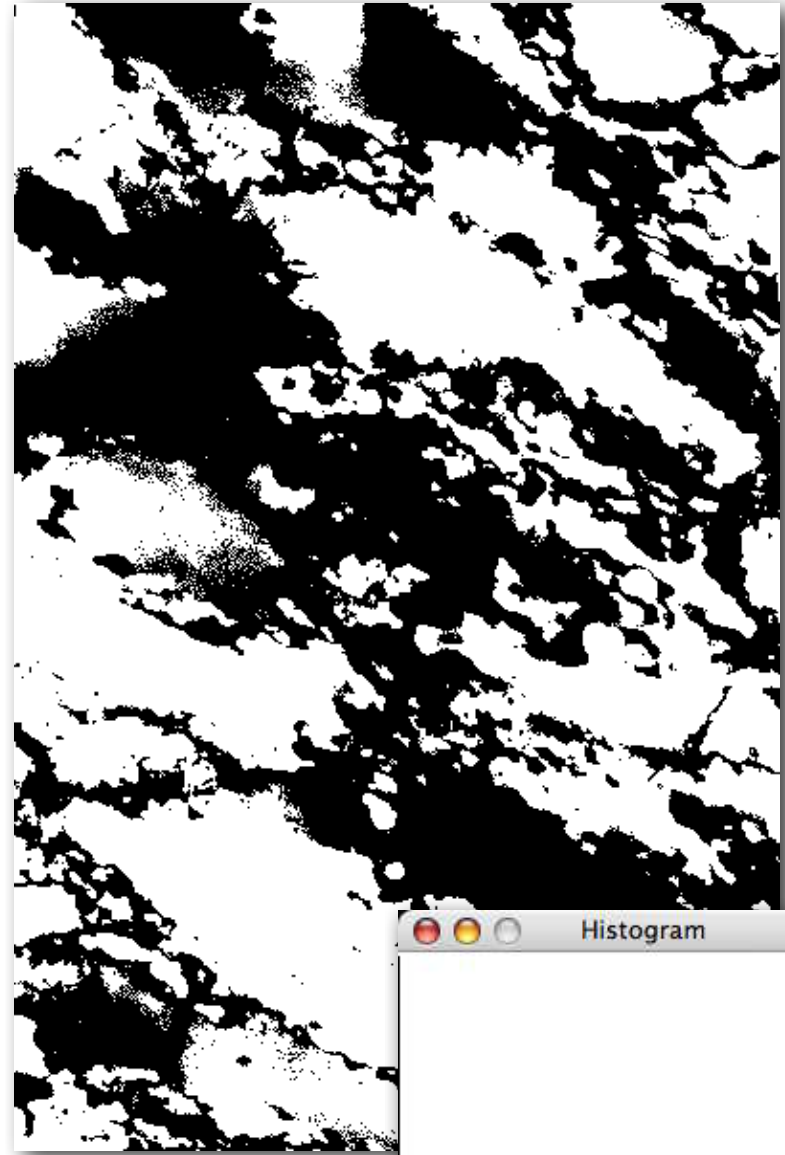
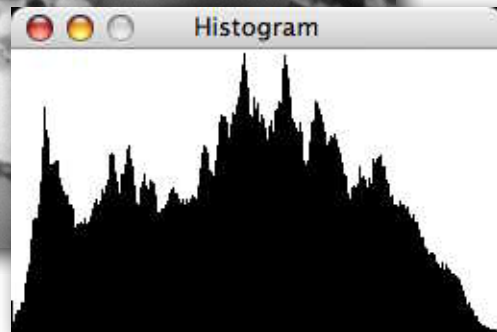
2 bit / pixel



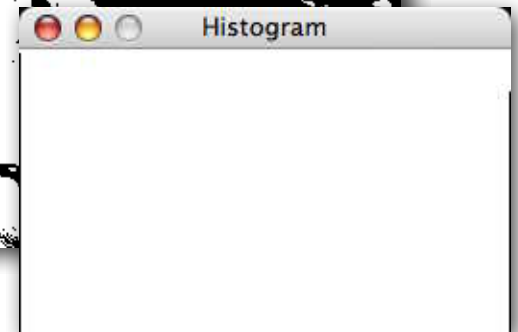




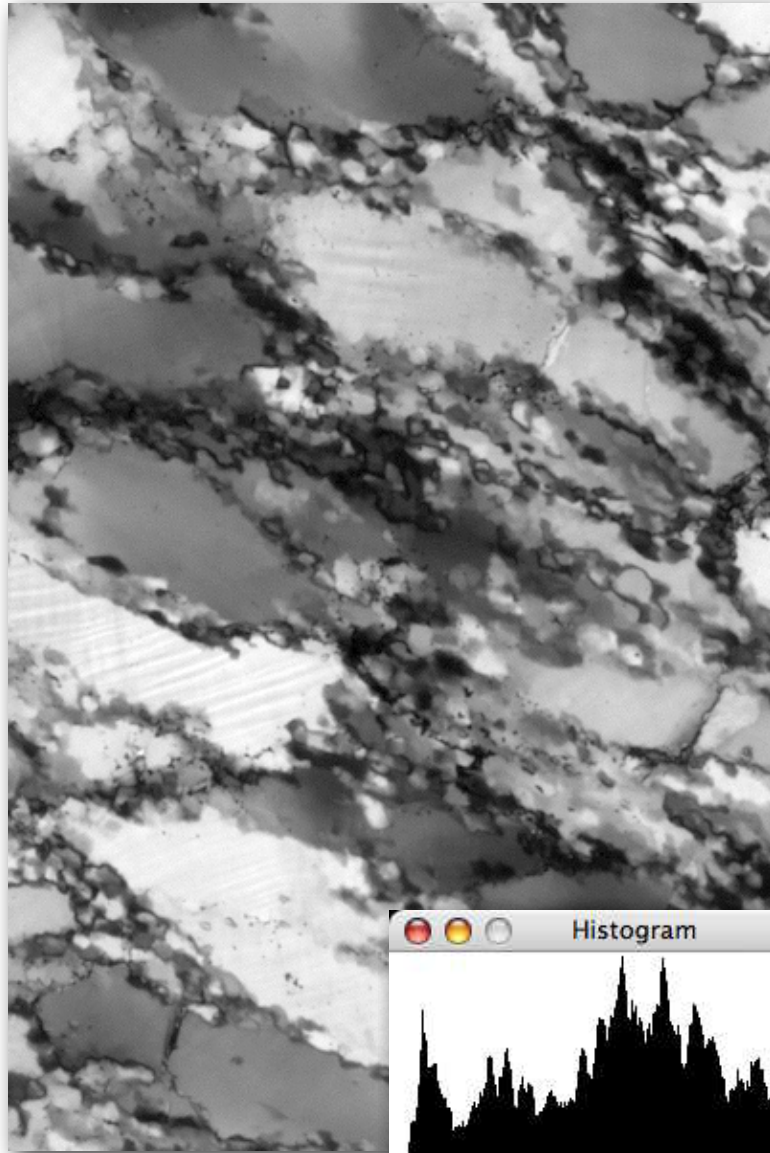
8 bit / pixel



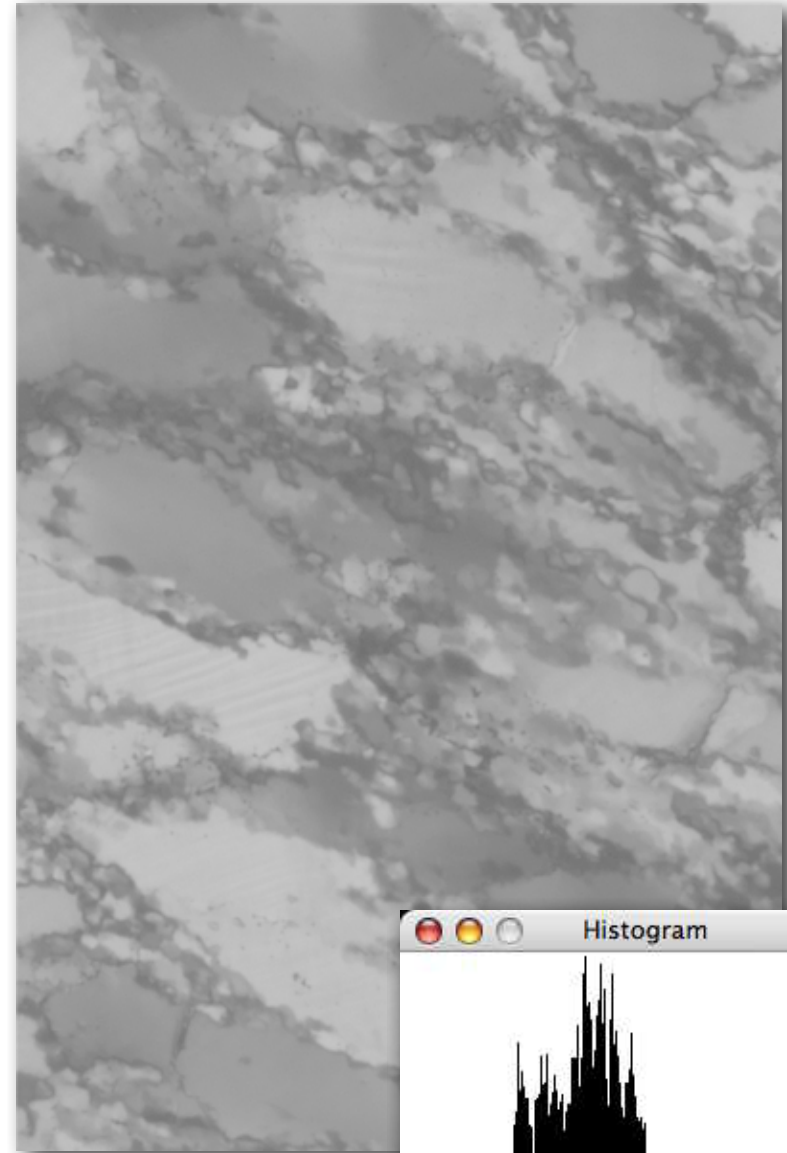
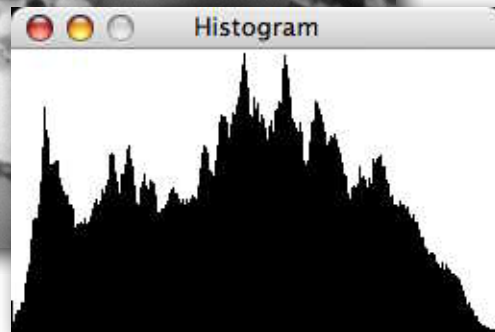
1 bit / pixel



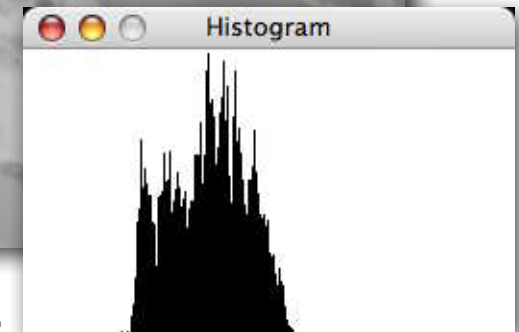
# Kontrastumfang

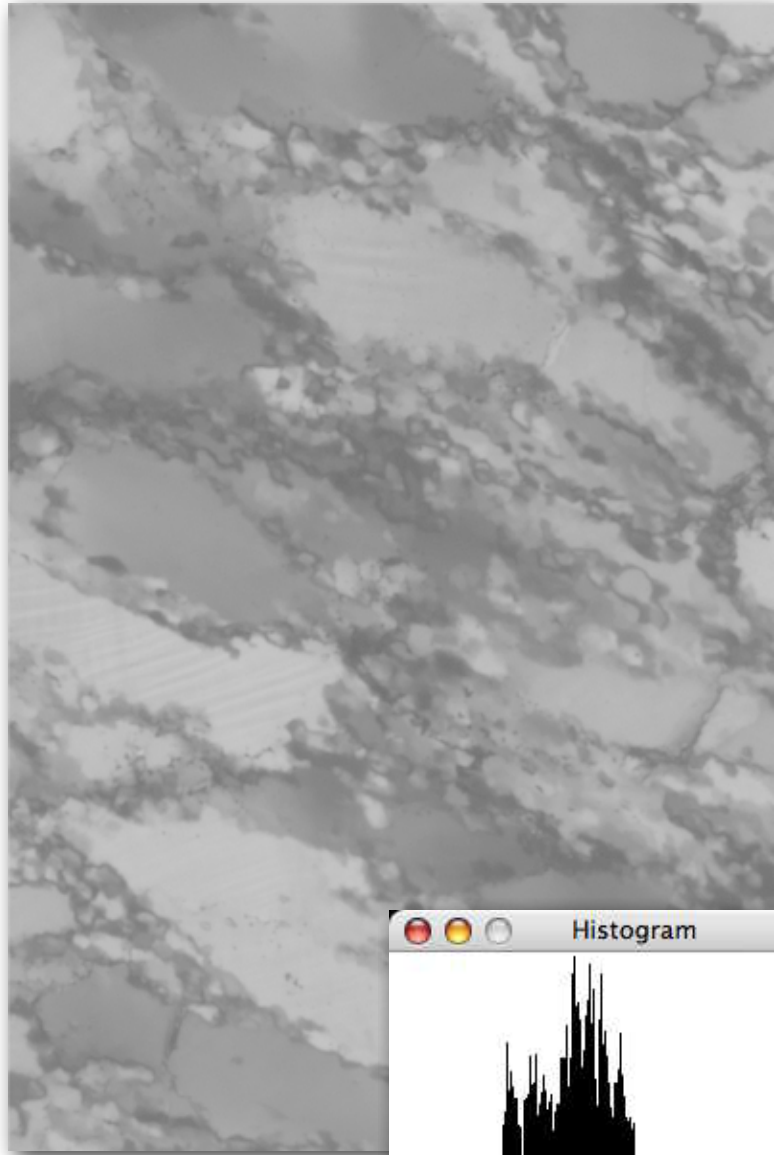


full range

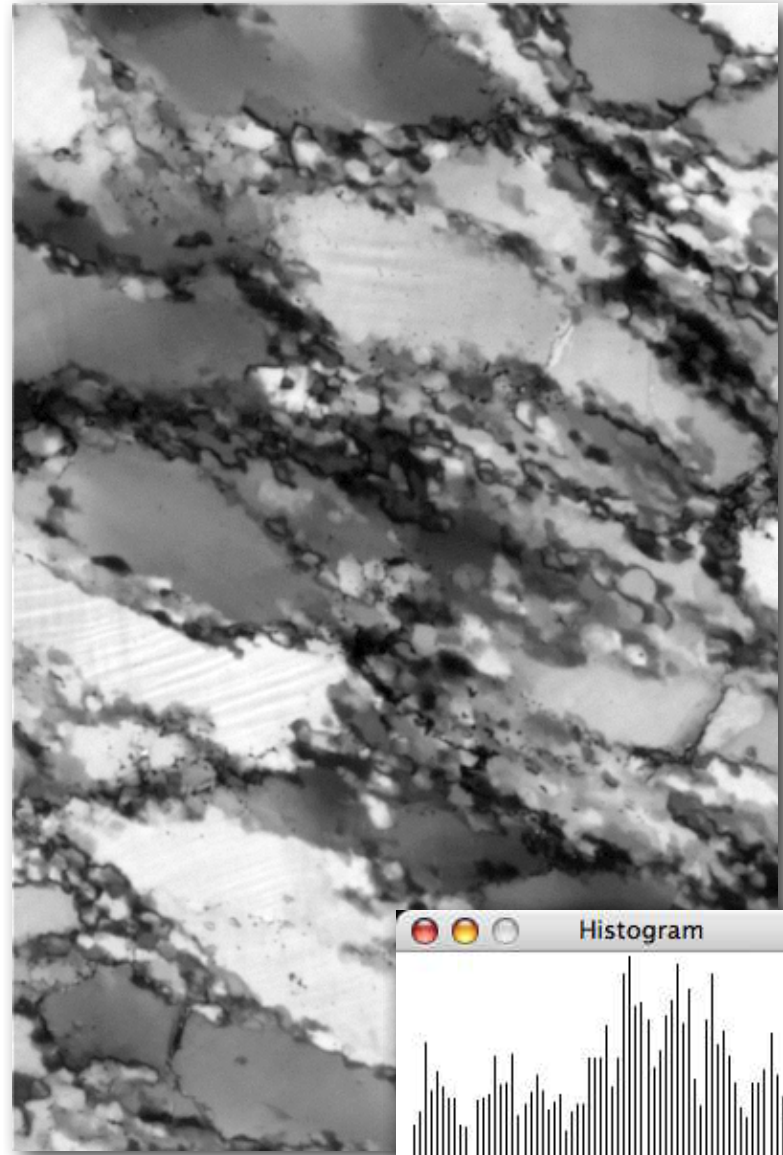
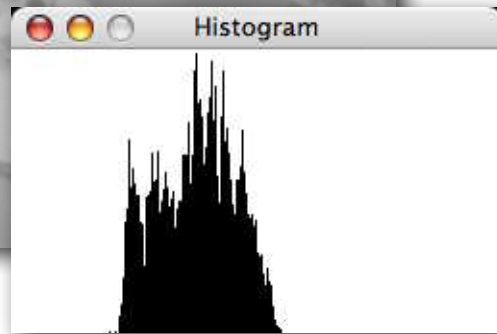


low contrast

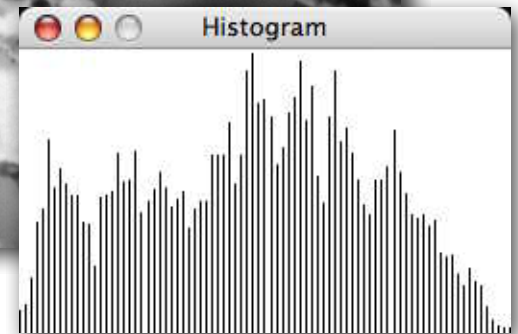




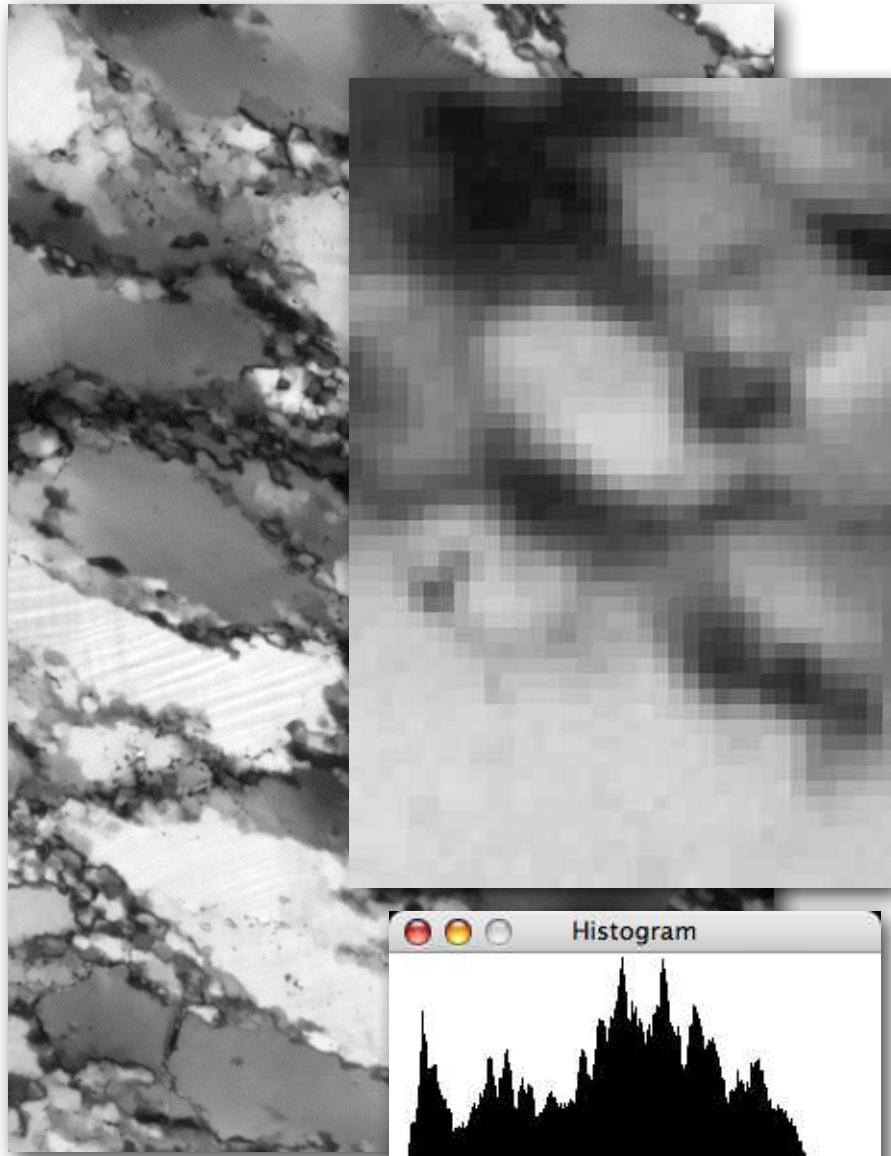
low contrast



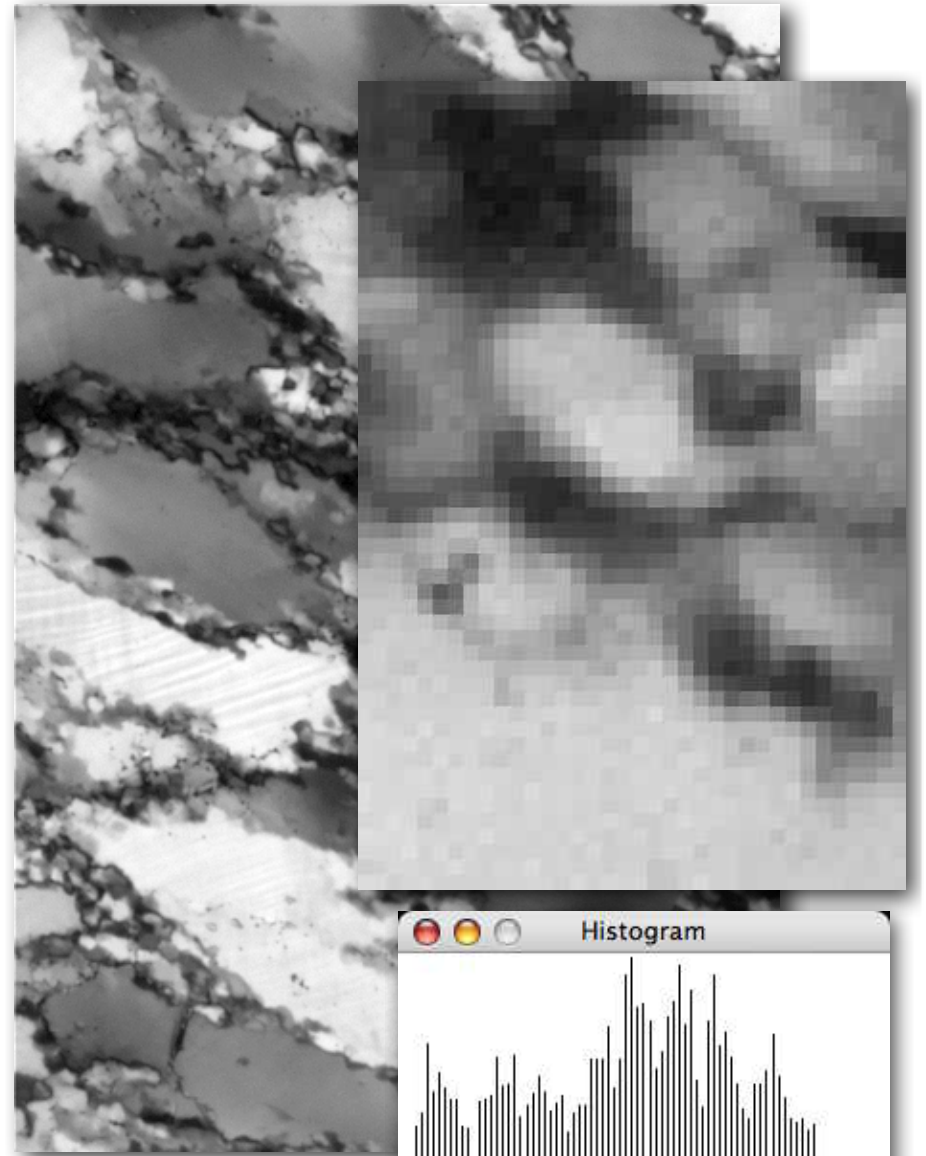
enhanced







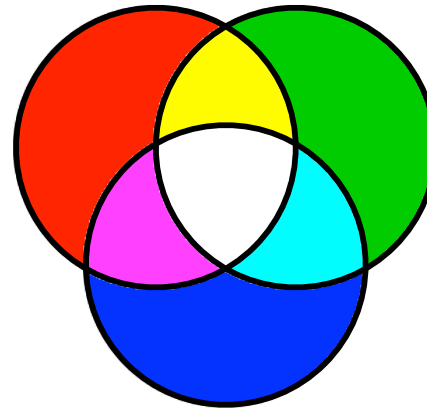
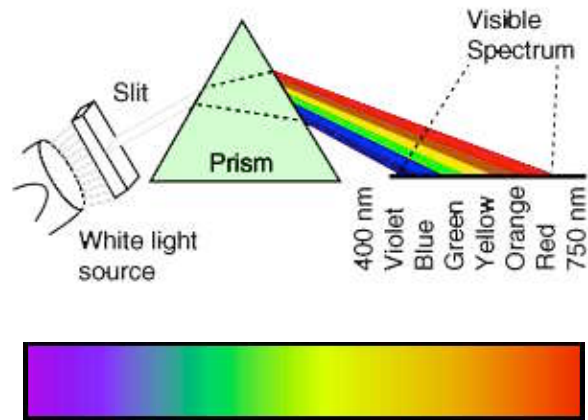
full range



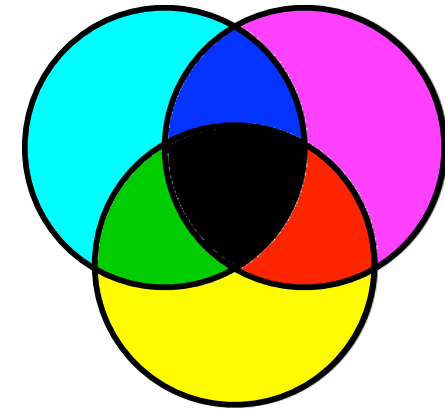
enhanced

# Farbe

# Farbsysteme



additiv  
Lichtmischung



subtraktiv  
Pigmentmischung

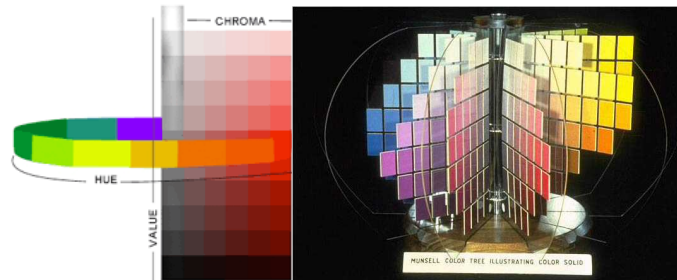
	R	G	B	C	M	Y
wavelength 400-500 nm						
500-600 nm						
600-700 nm						



# Farbsysteme



Caran d'Ache  
"Index" number

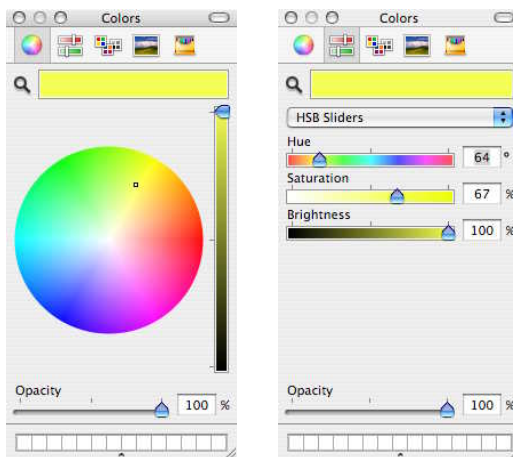


Munsell  
HSB



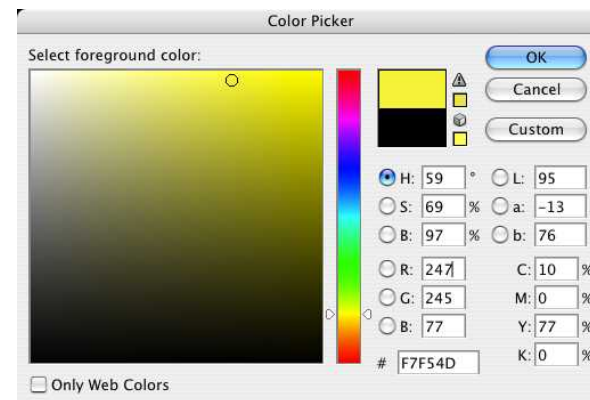
Pantone  
CMYK

## Apple color picker



Hue  
Saturation  
Brightness

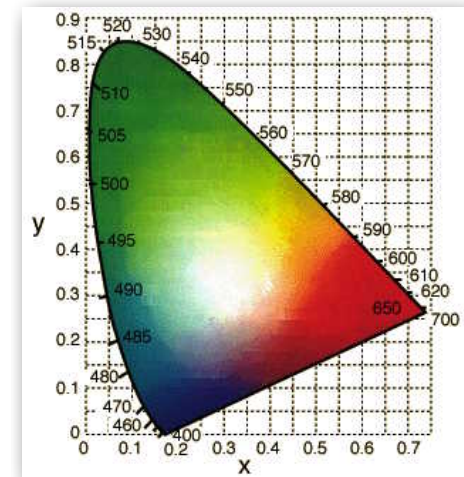
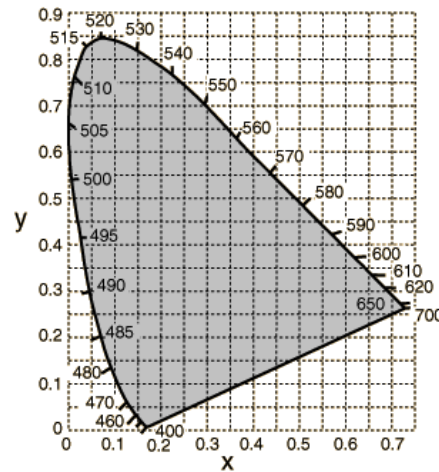
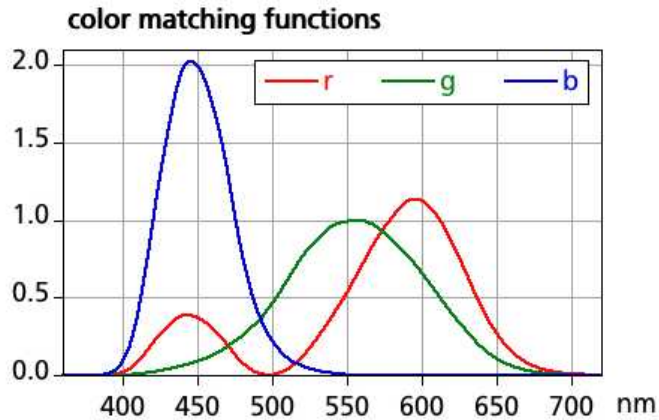
## Adobe color picker



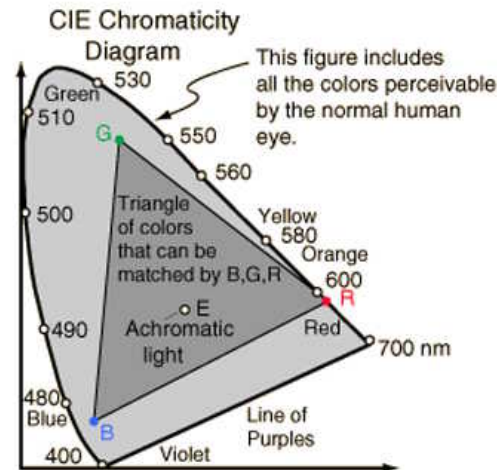
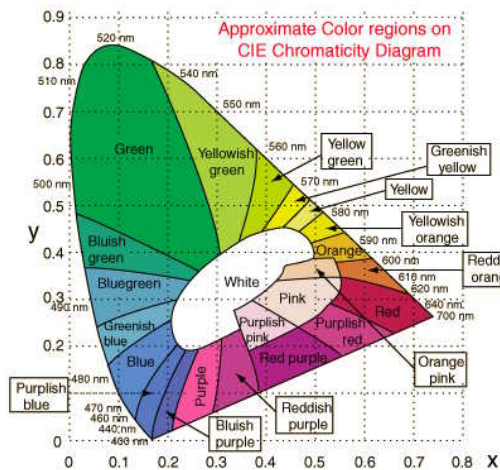
HSB  
RGB  
Lab  
CMYK  
hexadecimal

# Farbraum

Farbemessung CIE (commission internationale d'eclairage)

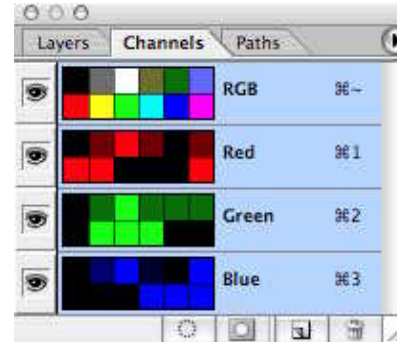
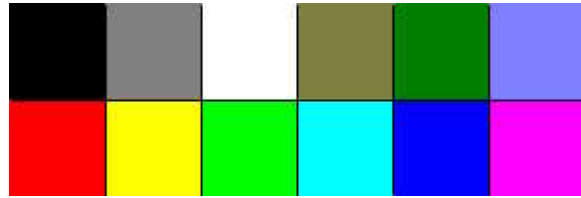


r g b Colour matching functions umgerechnet in x y z Chromaticity diagram



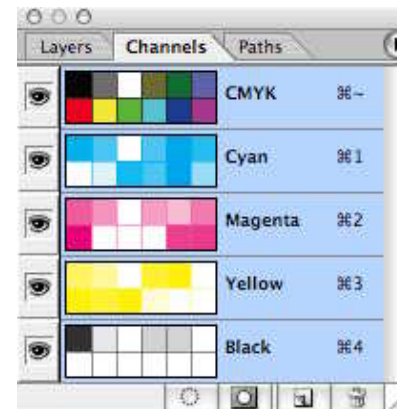
CIE chromaticity diagram: auf dem Computerschirm darstellbare Farben

# Farbdarstellung

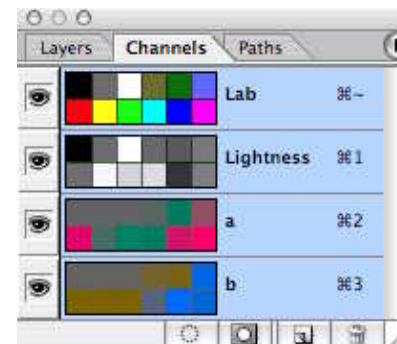
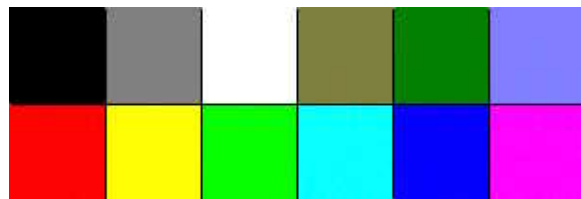


Photoshop Channels

RGB



CMYK



CIE: L a b



# Indexfarben



RGB (3 channels)  
size: 2.1 MB

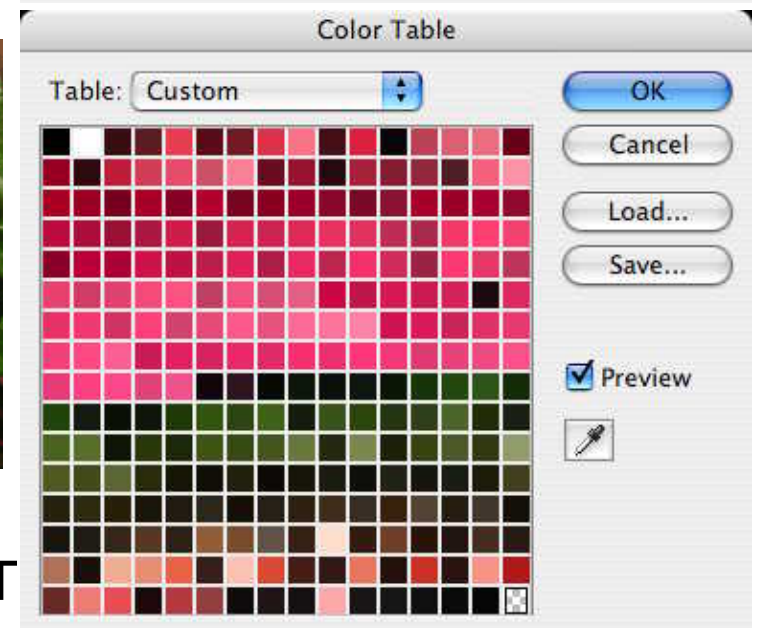
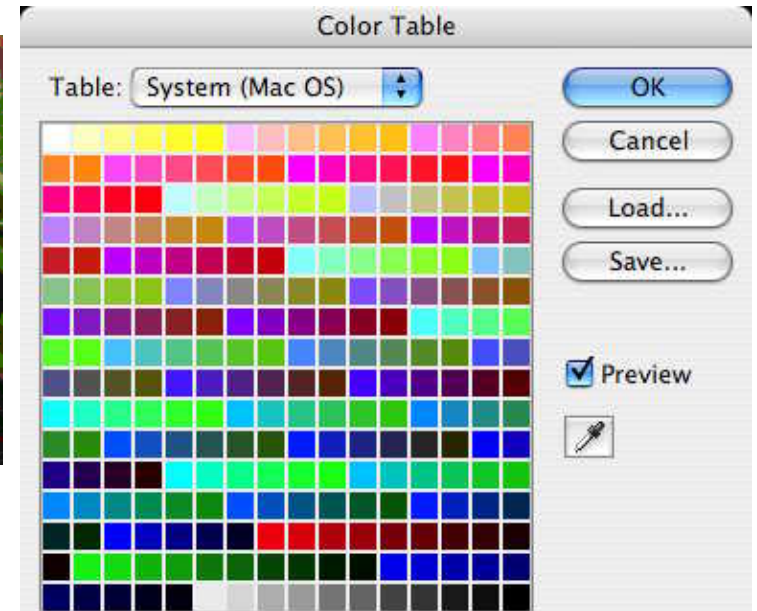


Index colours  
System Palette / LUT

Index (1 channel)  
size: 700 KB



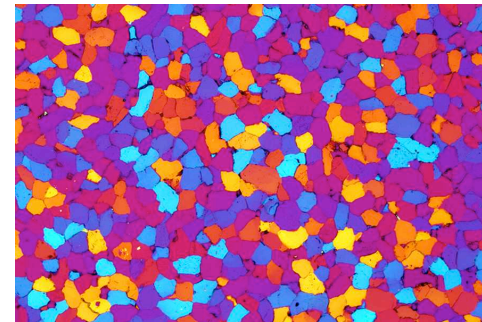
Index colours  
Perceptual Palette / LUT



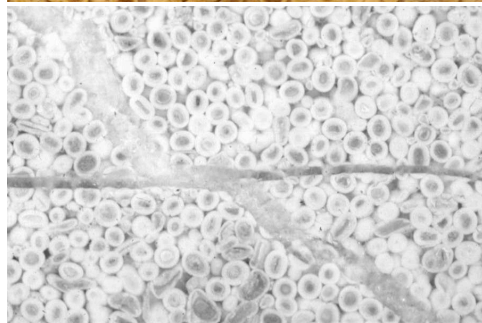
# RGB color



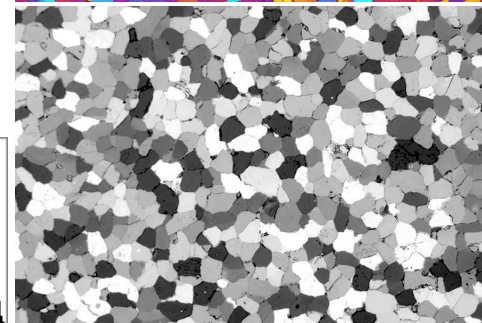
± monochromes Bild



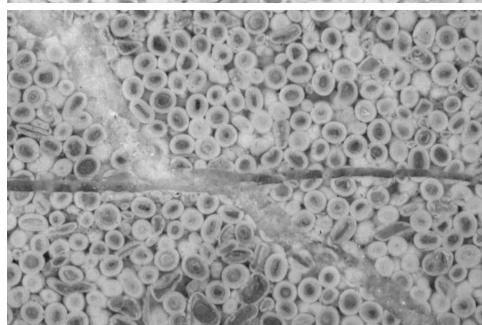
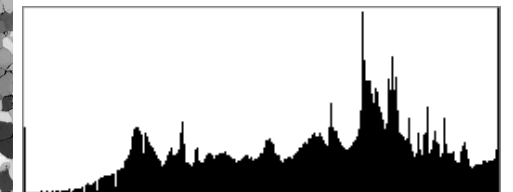
(viel-)farbiges Bild



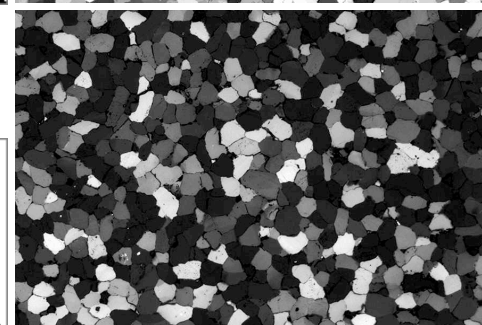
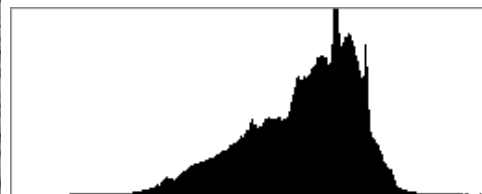
R



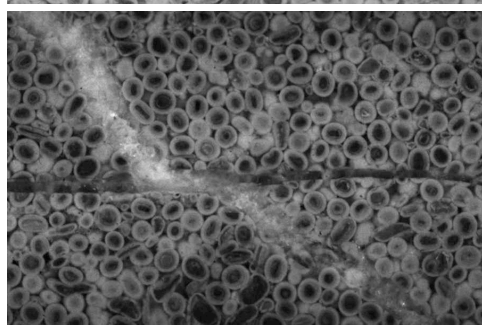
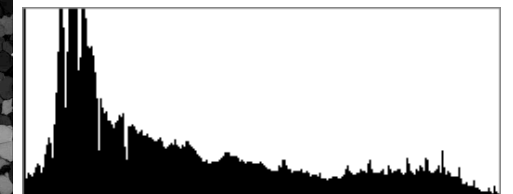
R



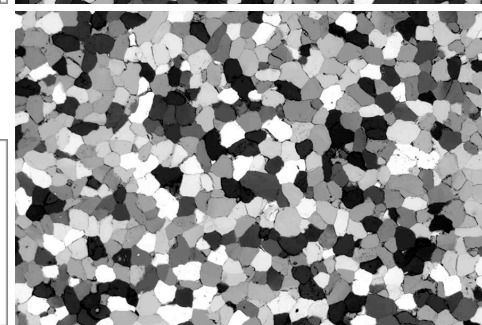
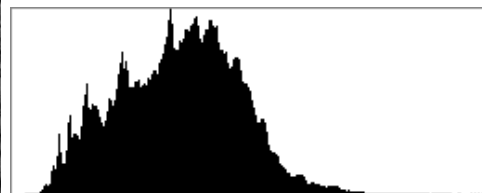
G



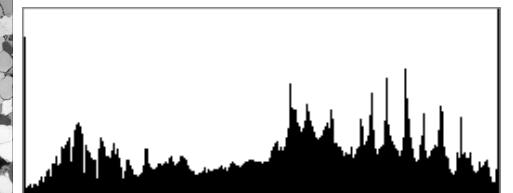
G



B

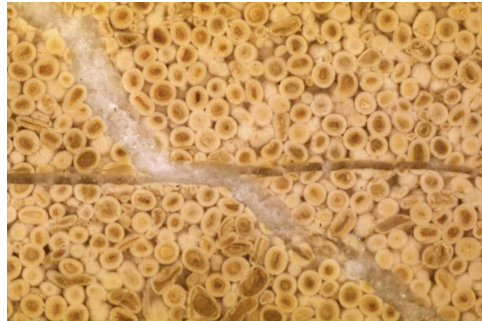


B

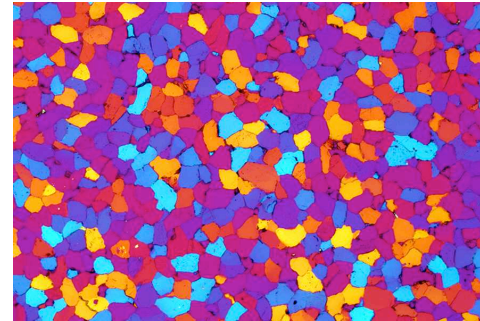




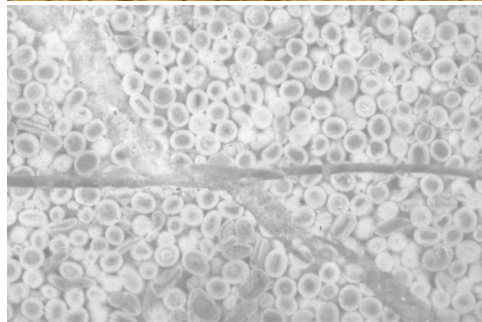
# CMYK color



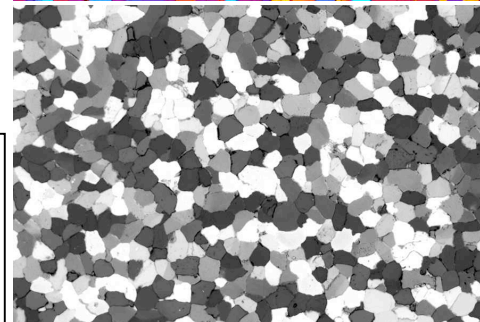
± monochromes Bild



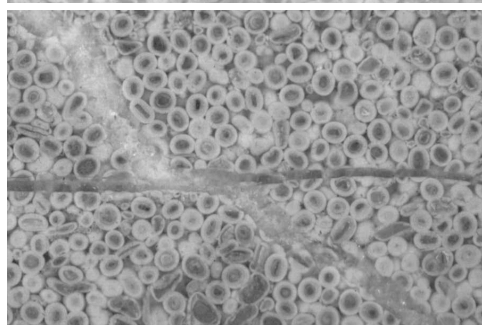
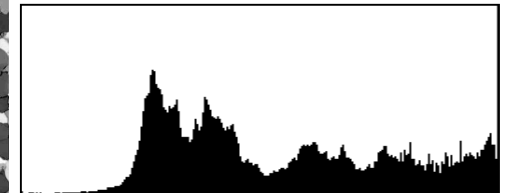
(viel-)farbiges Bild



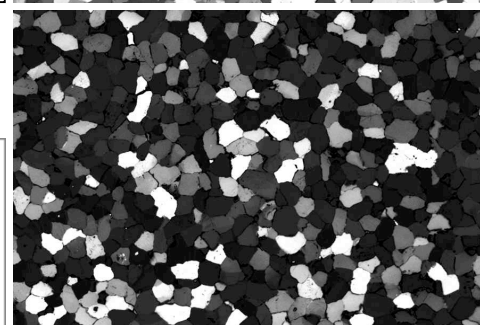
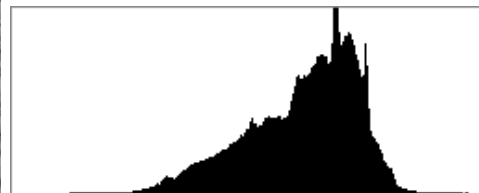
C



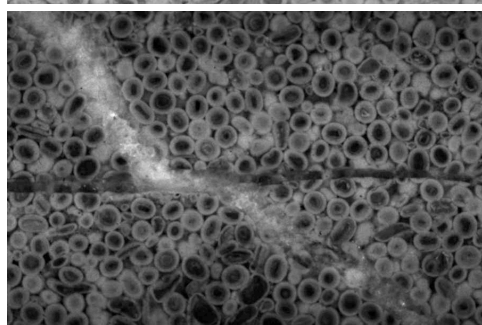
C



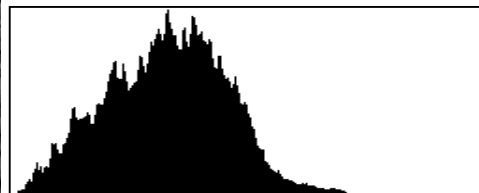
M



M



Y



Y

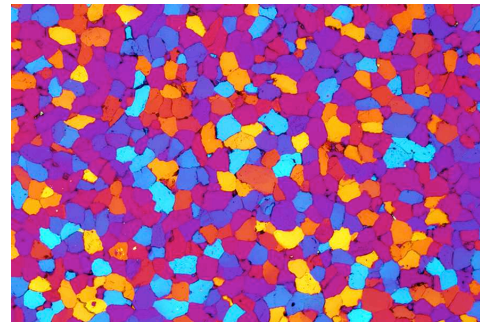




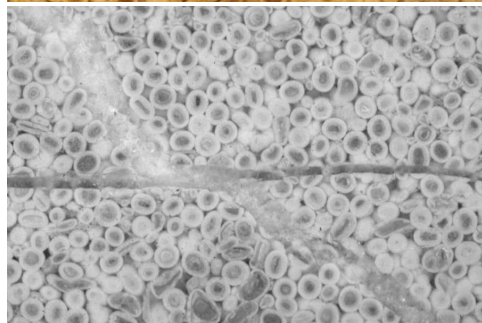
# Lab color



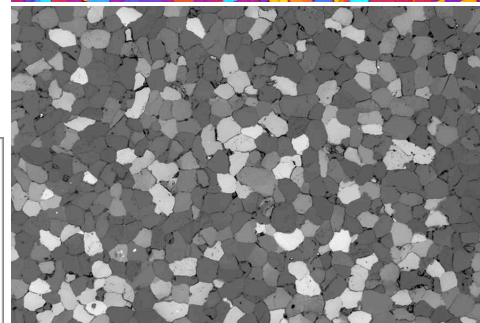
± monochromes Bild



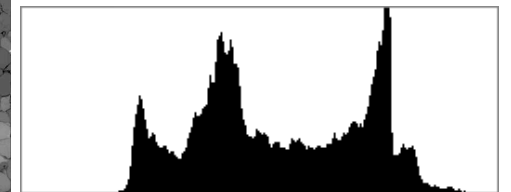
(viel-)farbiges Bild



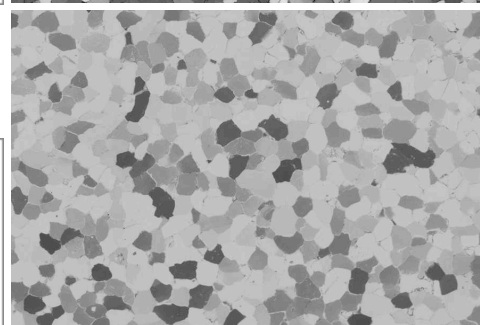
L



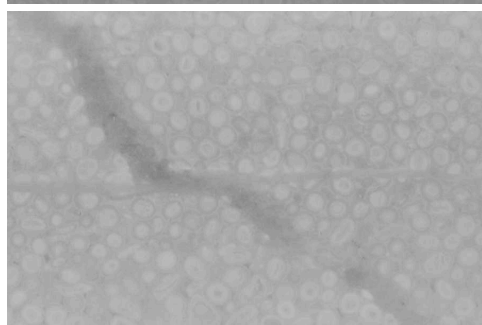
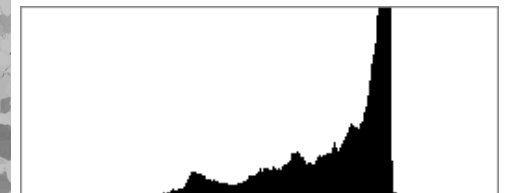
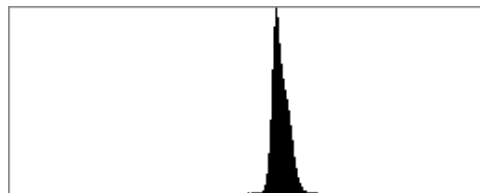
L



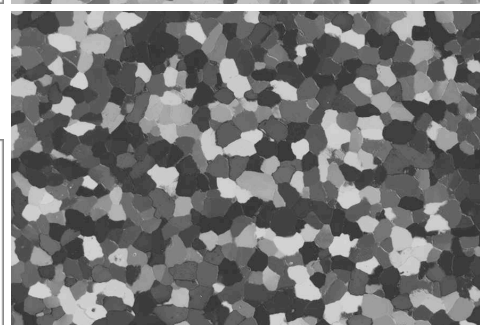
a



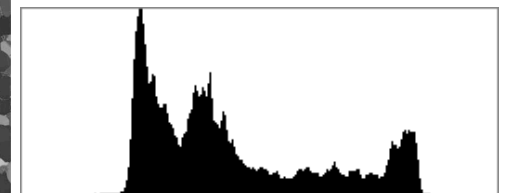
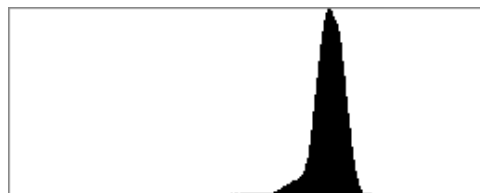
a



b



b



# Index color



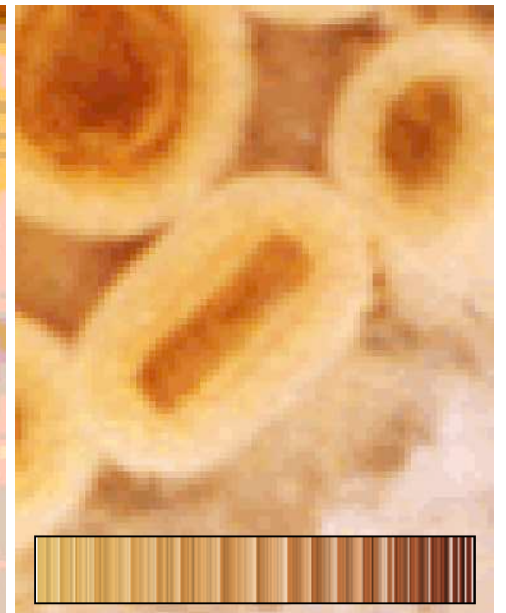
RGB



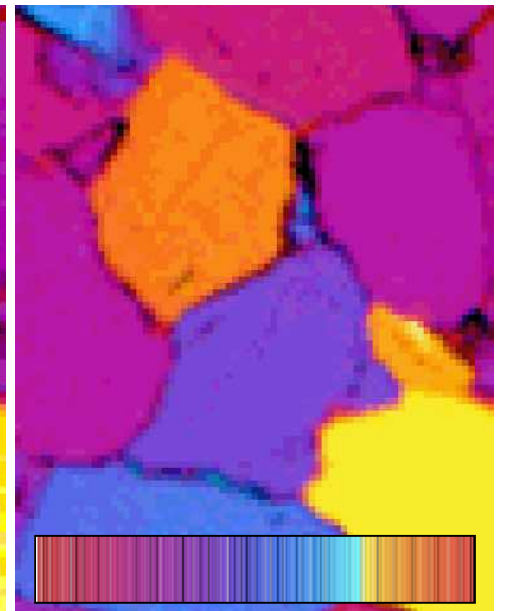
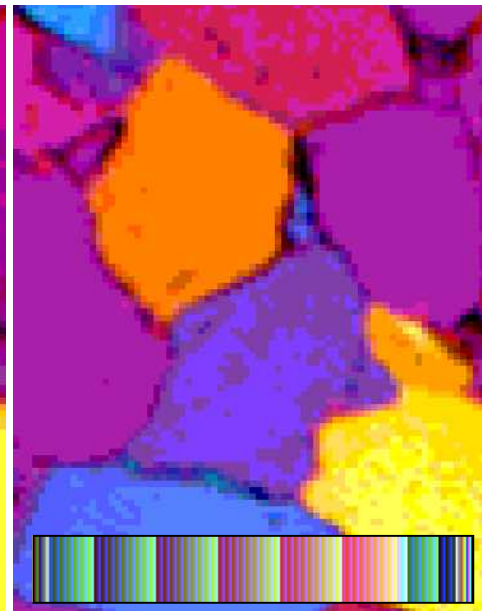
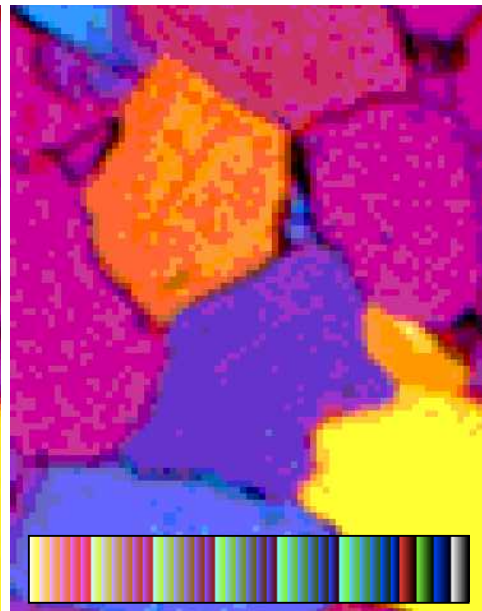
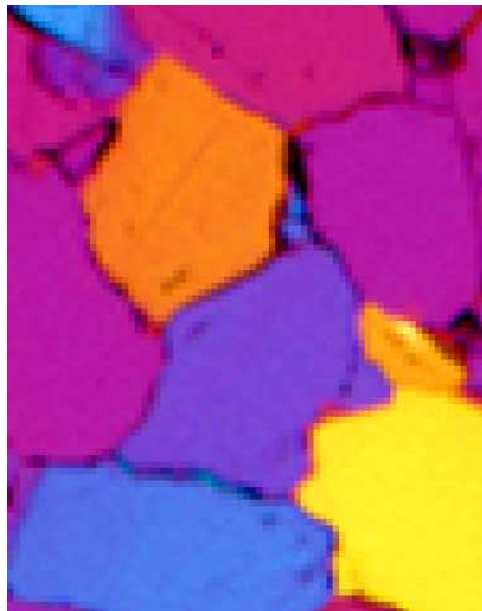
System (Mac OS)



System (MS Windows)

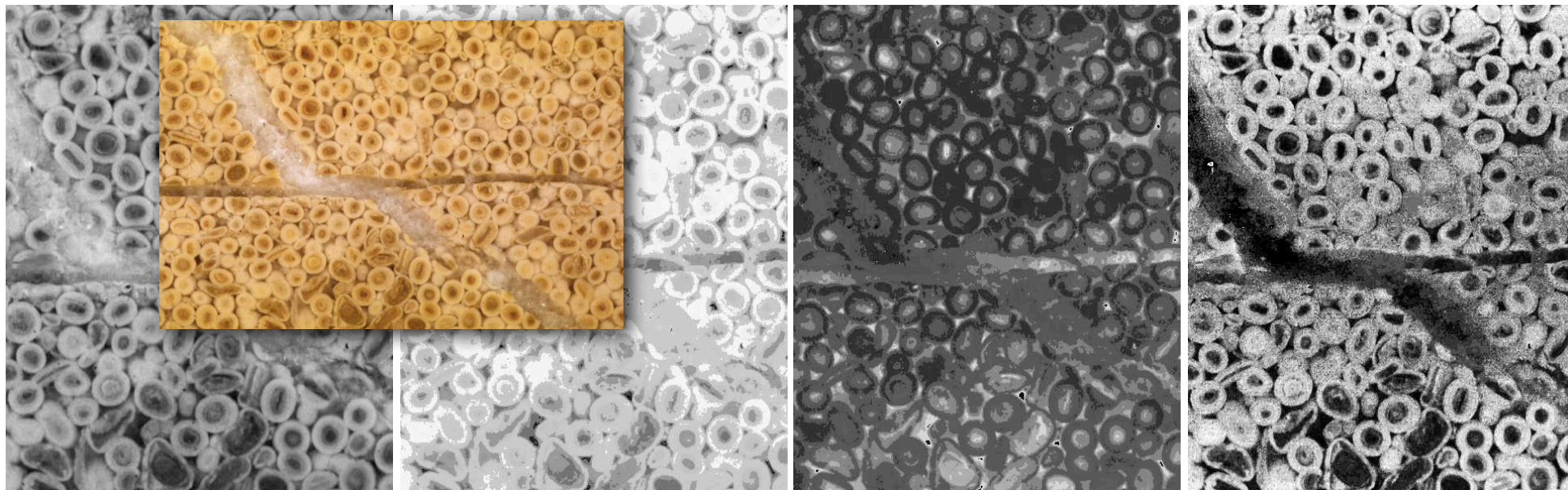


Adaptive





# Index Color to grayscale

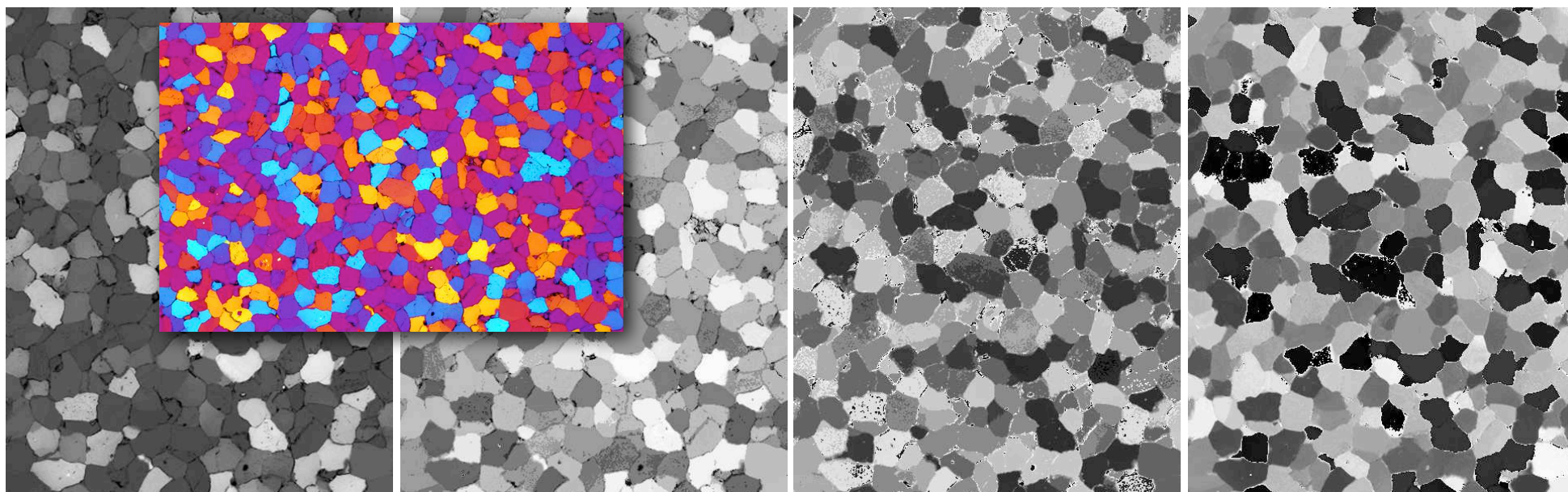


RGB

System (Mac OS)

System (MS Windows)

Adaptive

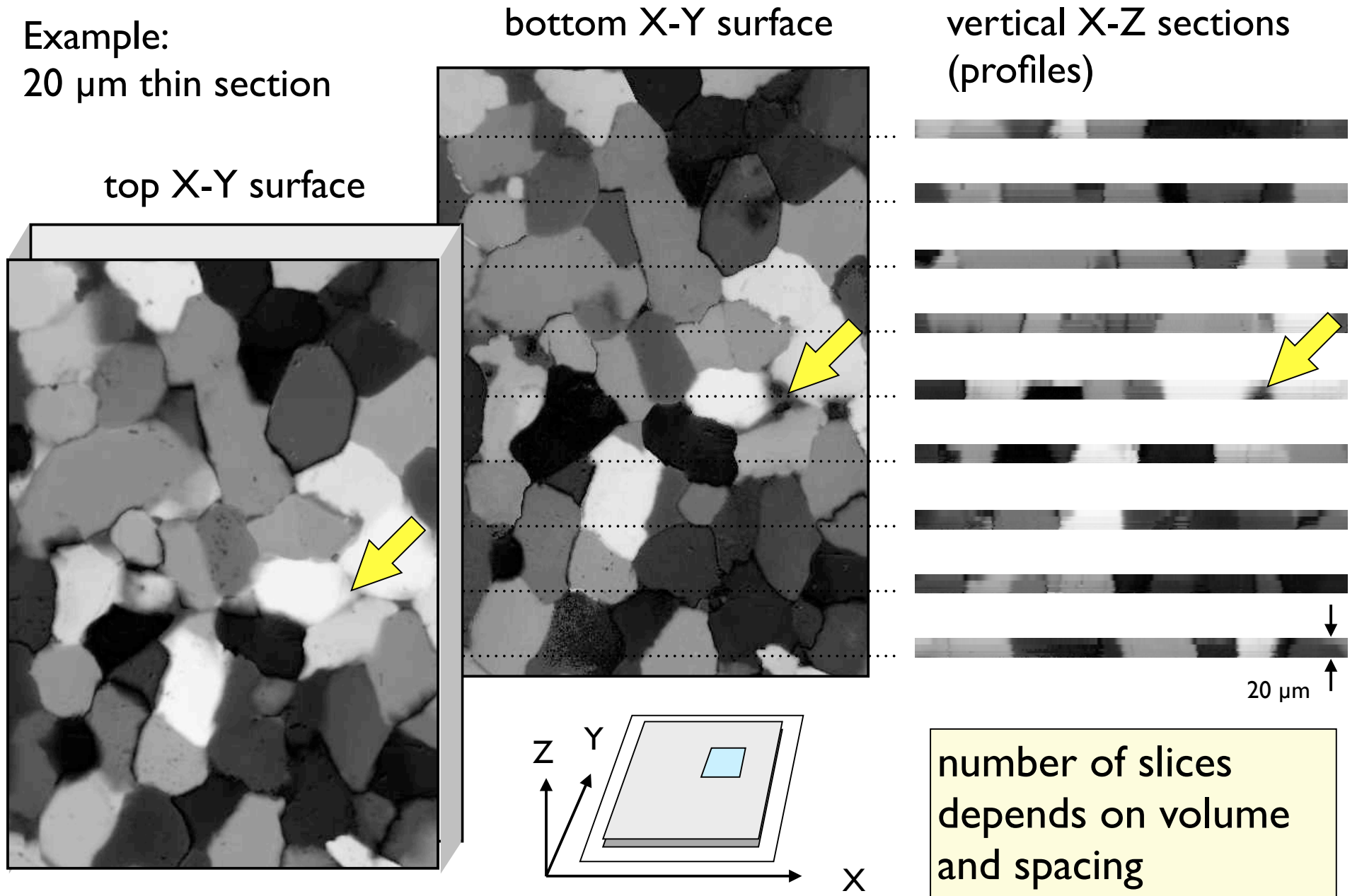




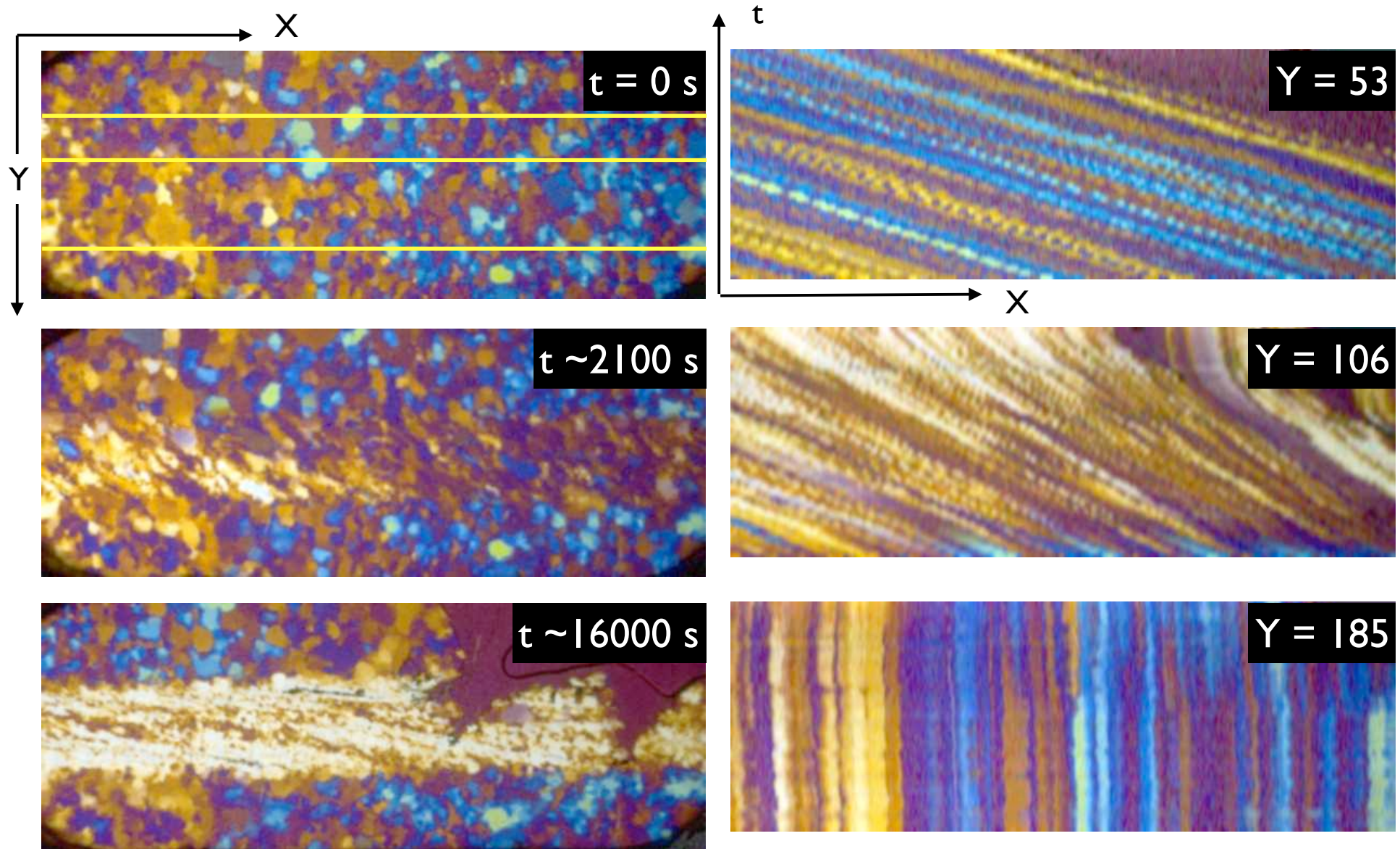
# Stacks

# XYZ volume stacks

Example:  
20  $\mu\text{m}$  thin section



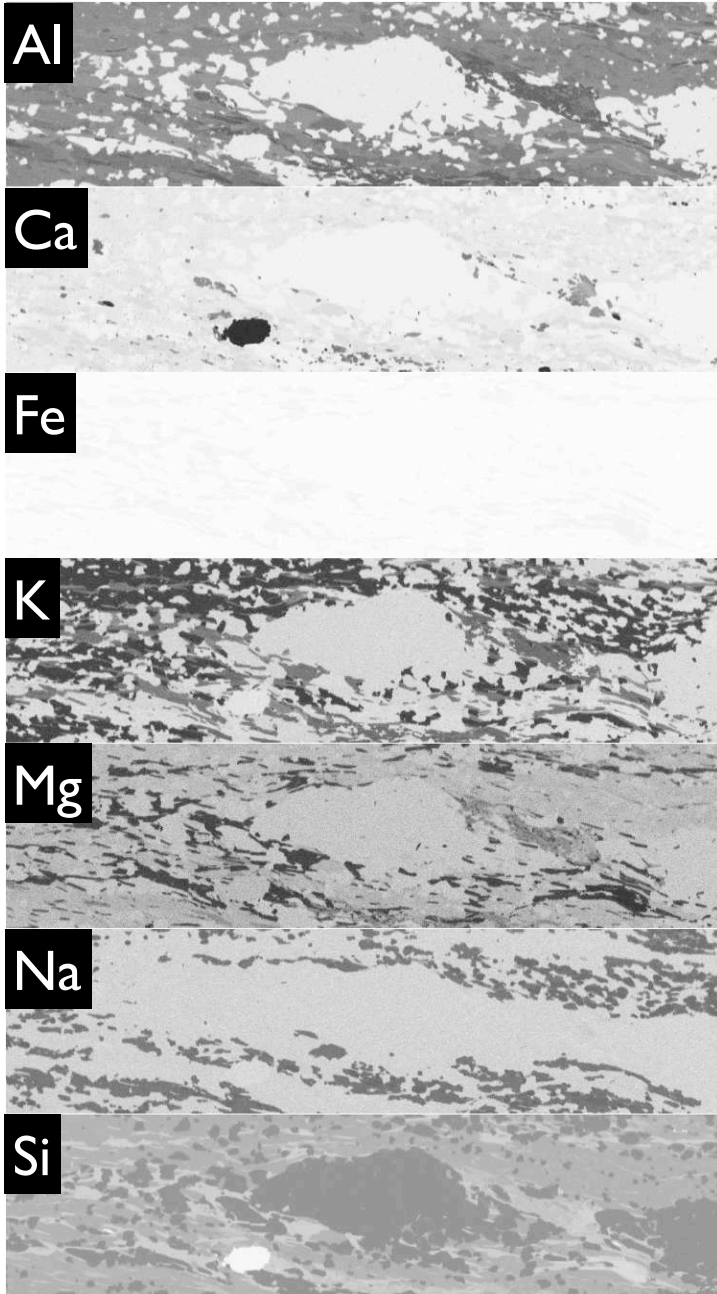
# XYt Time stacks (movies)



number of slices depends on duration and time interval (up to  $24 \text{ s}^{-1}$ )



# Multichannel image

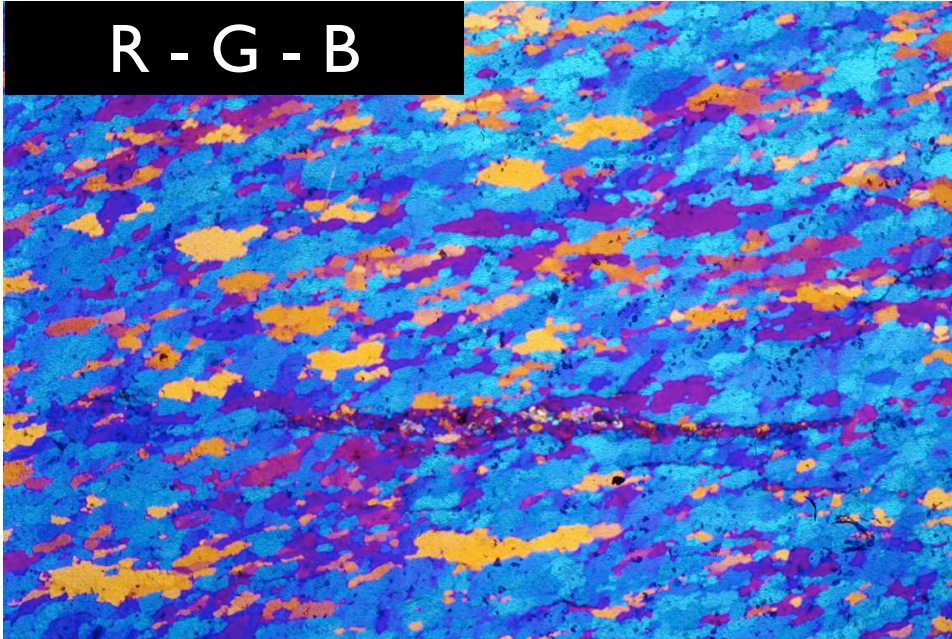


number of slices depends on  
number of channels (elements)

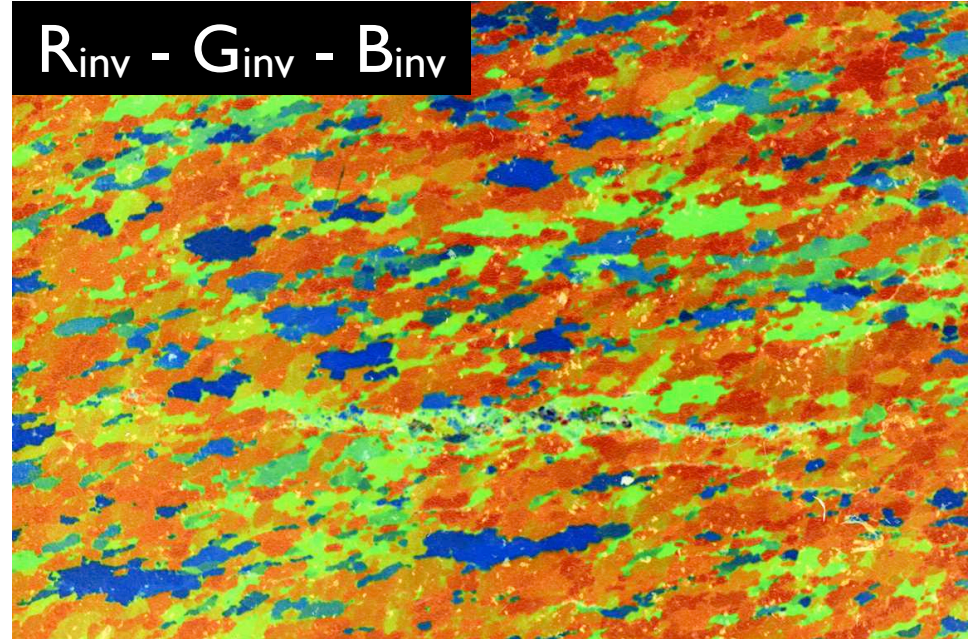


# Color stacks

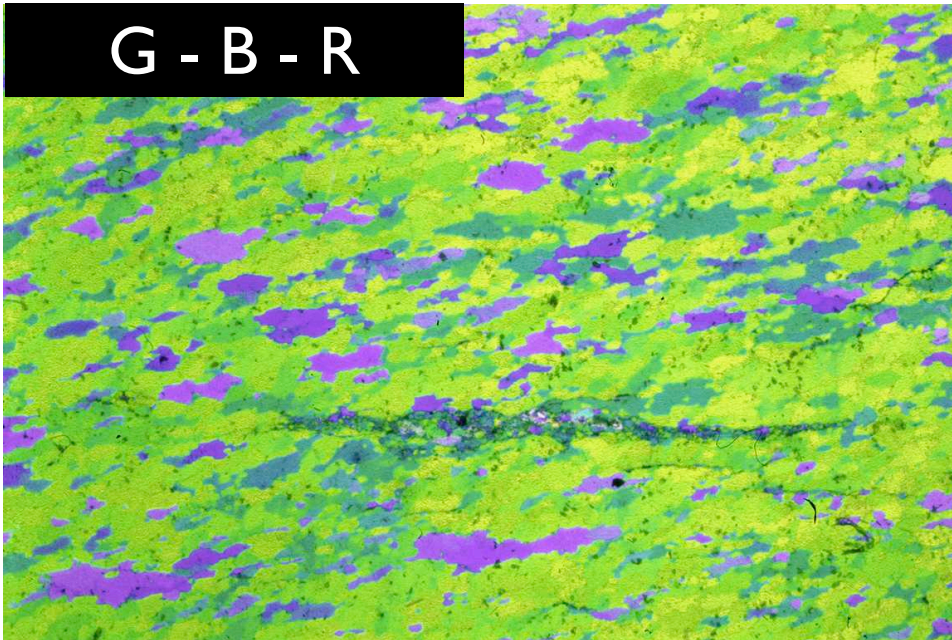
R - G - B



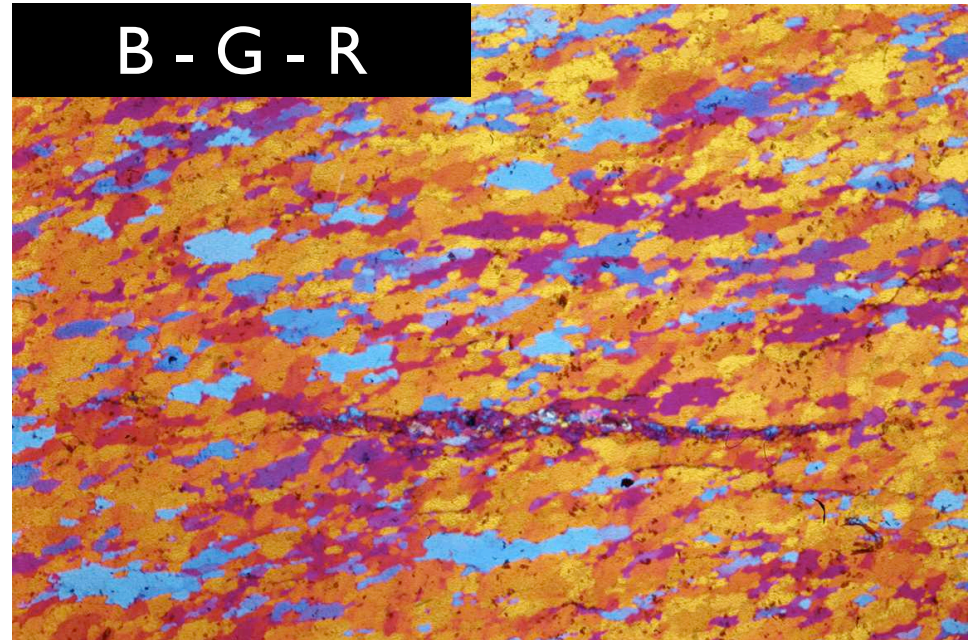
$R_{inv}$  -  $G_{inv}$  -  $B_{inv}$



G - B - R

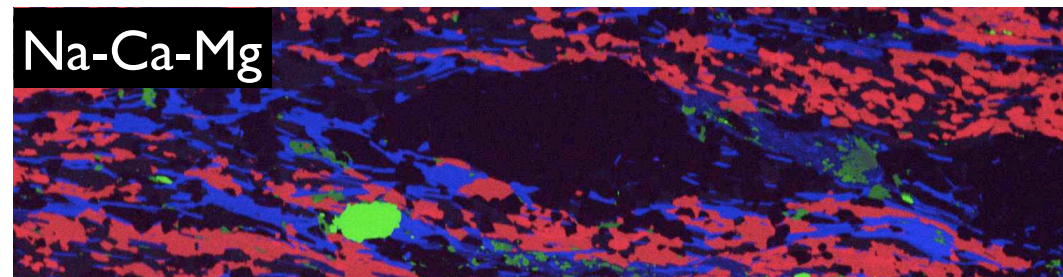
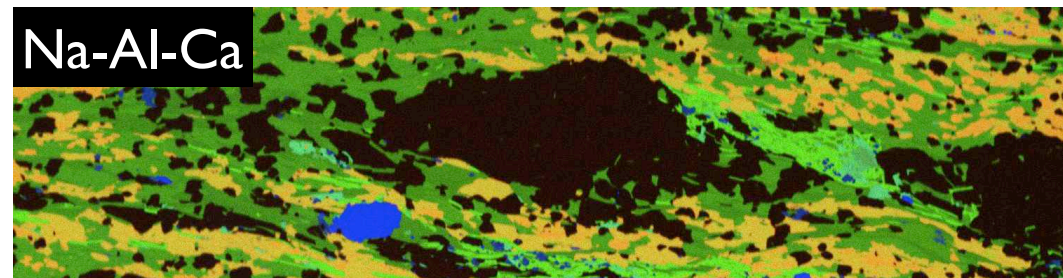
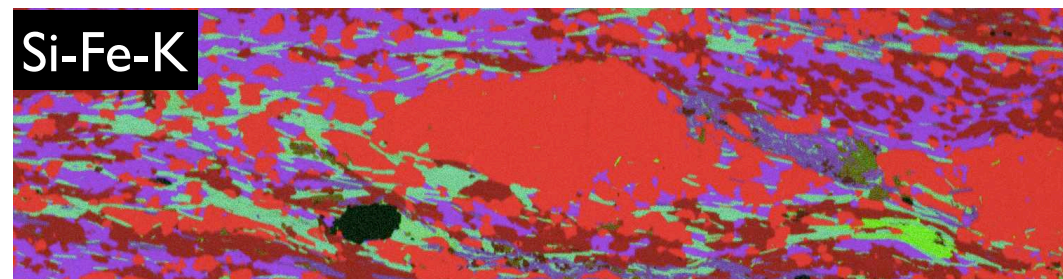
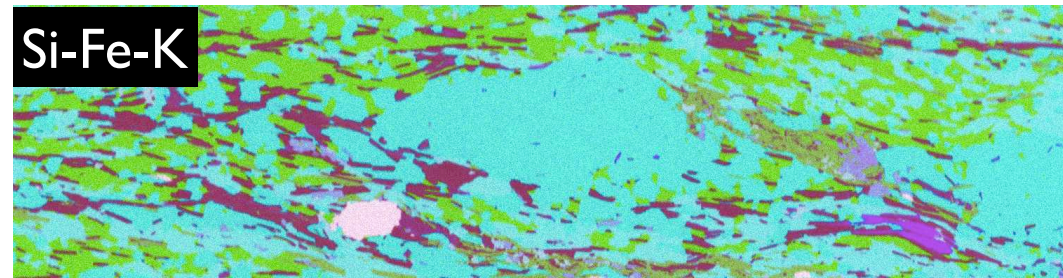
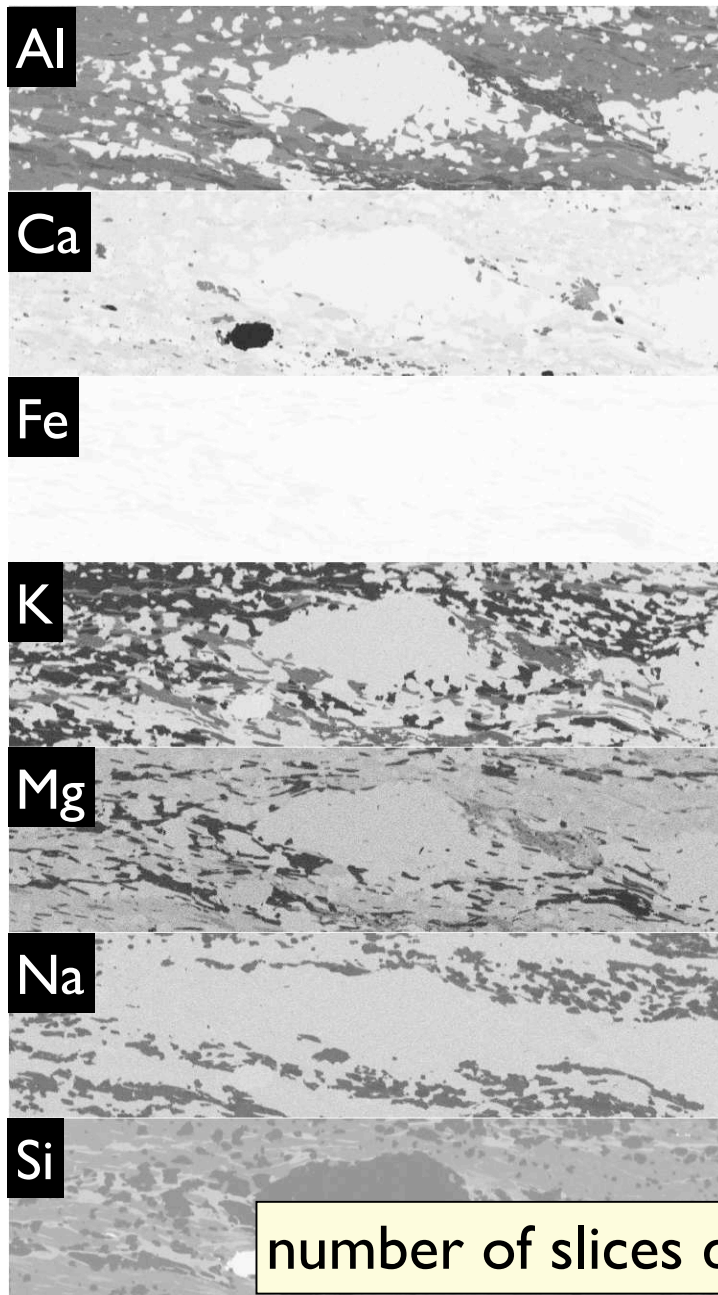


B - G - R





# Multichannel image



number of slices depends on number of channels (elements)



# Übung 2 - Beugung und Auflösung

## Wellenoptische Grenzen der Auflösung

- Öffnen Sie folgenden (höchst empfehlenswerten) Link:

<http://www.cambridgeincolour.com/tutorials/diffraction-photography.htm>

## Pixel- bzw. Sensorgröße

- Öffnen Sie den Link:

<http://www.cambridgeincolour.com/tutorials/digital-camera-sensor-size.htm>

Überprüfen Sie die Leistung Ihrer eigenen Kamera (eventuell iPhone o.ä.)

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### LENS DIFFRACTION

Diffraction is an optical effect which limits how many megapixels your camera can resolve. Light rays passing through a small aperture will begin to diverge and interfere with one another. This becomes more significant as the size of the aperture decreases relative to the wavelength of light passing through, but occurs to some extent for any aperture or concentrated light source.

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### BACKGROUND

Light rays passing through a small aperture will begin to diverge and interfere with one another. This becomes more significant as the size of the aperture decreases relative to the wavelength of light passing through, but occurs to some extent for any aperture or concentrated light source.

Large Aperture Small Aperture

### Advanced Concepts

- ▶ Digital Camera Sensor Sizes: How Do These Influence Photography?
- ▶ Understanding Diffraction: Pixel Size, Aperture and Airy Disks
- ▶ Digital Cameras vs. The Human Eye (NEW)
- ▶ Understanding the Hyperfocal Distance

# DBA 2014


## session 2

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
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→ VIA - Vorlesungsverzeichnis  
→ PERSSEARCH - Personensuche

HOME Contact Studium Geowissenschaften Lehrveranstaltungen Vorträge und Links Strukturgeologie  
Rock Deformation Projects & Software Workshops Textbook DDM Macros ImageJ Macros Image Analysis

LEHRVERANSTALTUNGEN



...l'appel des cimes de René Magritte...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehölle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageEXM bzw. ImageJ kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageEXM software (Mac/OSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Exportation (2-D -> 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software Image EXM, bzw. ImageJ (alle public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungbestellung möglich)
- Harterter, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET**

earth.unibas.ch  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

TRIMISS GEO-IMAGING

→ TRIMISS CRISTAL DYNAMICS HOMEPAGE (English)  
→ TRIMISS GEOLOGY HOMEPAGE (Norwegian)  
→ TRIMISS UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>

# Übung 2 - Beugung und Auflösung

## Wellenoptische Grenzen der Auflösung

- Öffnen Sie folgenden (höchst empfehlenswerten) Link:

<http://www.cambridgeincolour.com/tutorials/diffraction-photography.htm>

## Pixel- bzw. Sensorgröße

- Öffnen Sie den Link:

<http://www.cambridgeincolour.com/tutorials/digital-camera-sensor-size.htm>

Überprüfen Sie die Leistung Ihrer eigenen Kamera (eventuell iPhone o.ä.)

The screenshot shows the Cambridge in Colour website interface. The main content area is titled 'LENS DIFFRACTION' and contains the following text: 'Diffraction is an optical effect which limits how many megapixels your camera can resolve. Light rays normally diffract when passing through a small aperture, since smaller apertures have larger aberrations. However, for sufficiently small apertures, the effect is normally negligible, since smaller apertures have less aberrations. It can help to maximize detail, and avoid an unnecessarily long exposure or high ISO speed.' Below this is a 'BACKGROUND' section with two diagrams: 'Large Aperture' showing parallel light rays and 'Small Aperture' showing diverging light rays. A sidebar on the right lists 'BROWSE CATEGORIES' including 'Concepts & Terminology', 'Using Camera Equipment', 'Editing & Post-Processing', 'Color Management & Printing', and 'Photo Techniques & Styles'. A top navigation menu includes 'HOME', 'TOOLS', 'TUTORIALS', and 'FORUMS'. A search bar is located in the top right corner.

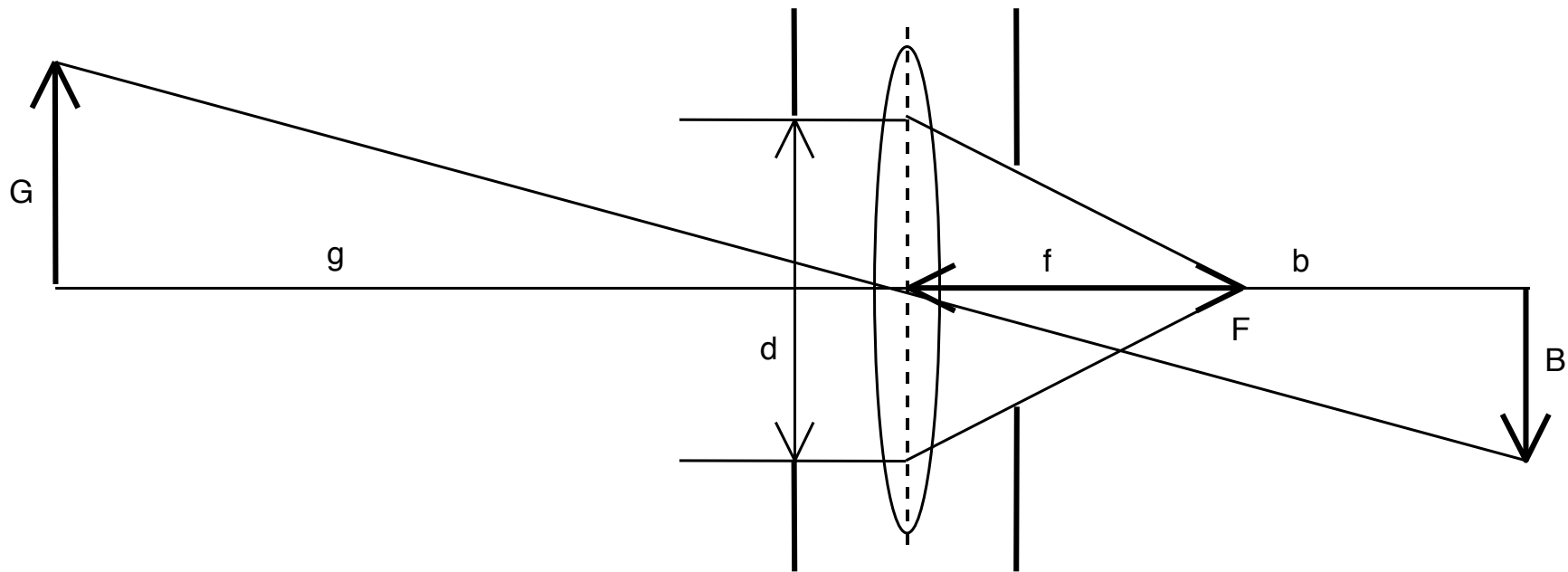
The screenshot shows the 'Advanced Concepts' page on the Cambridge in Colour website. The page features a list of four articles related to digital camera sensor sizes and diffraction:

- ▶ Digital Camera Sensor Sizes: How Do These Influence Photography?
- ▶ Understanding Diffraction: Pixel Size, Aperture and Airy Disks
- ▶ Digital Cameras vs. The Human Eye (NEW)
- ▶ Understanding the Hyperfocal Distance



# Optische Grenzen

# Geometrische Optik



f Brennweite

F Brennpunkt

g Gegenstandsweite

G Gegenstandsgrösse

b Bildweite

B Bildgrösse

d Durchmesser der wirksamen Öffnung

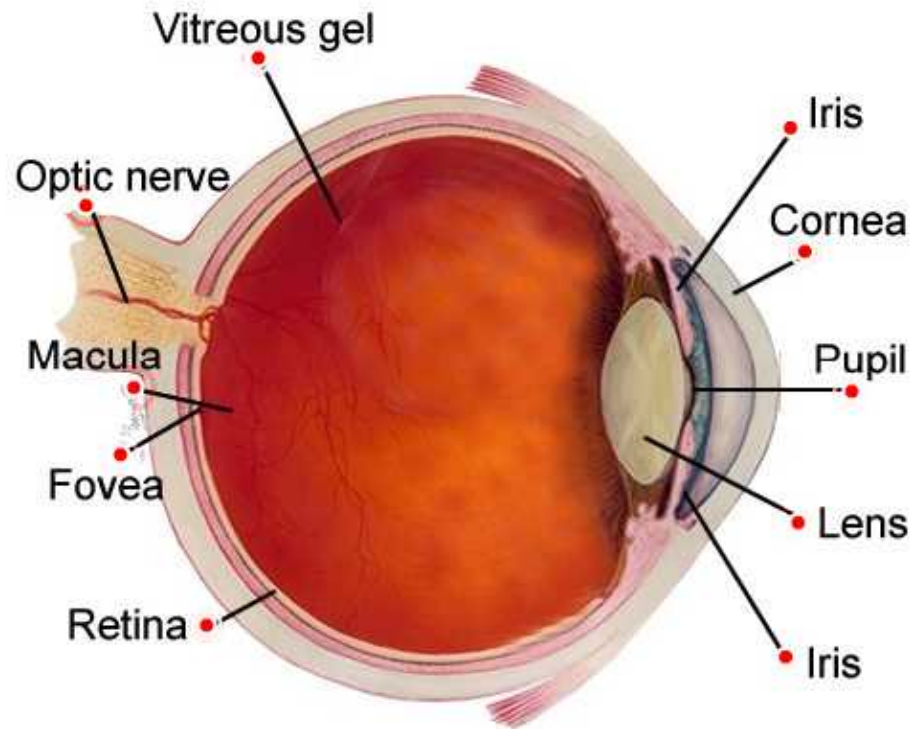
k Blendenzahl

m Abbildungsmassstab =  $B / G$

grosse Blendenzahl = hohe Schärfentiefe

kleine Blendenzahl = hohe Auflösung

# spatial resolution: eye



das menschliche Auge

Winkelauflösung  
 $\approx 1^\circ$  ( $\approx 60$  Bogenminuten)

$\approx 0.4$  mm  
in 250 mm Distanz

objektseitige Brennweite: 16.7 mm  
bildseitige Brennweite: 22.3 mm



# spatial resolution: microscopes

Lichtmikroskop - optische Auflösung



10x magnifying power  
/ 0.30 numerical aperture

$$d = \lambda / nA = \lambda / (n \cdot \sin(\alpha))$$

d smallest resolved distance

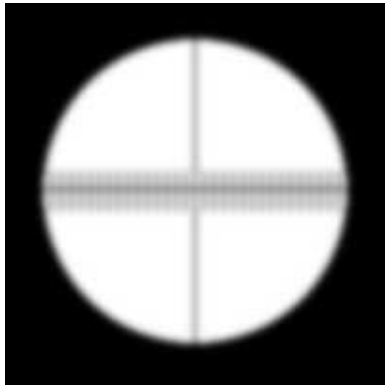
nA numerical aperture

$\lambda$  wavelength

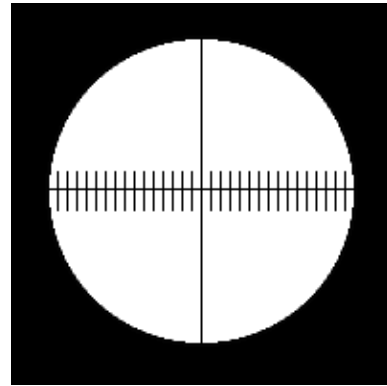
n refractive index of medium  
(air = 1.00, oil = 1.55)

$\alpha$  opening angle of optical system

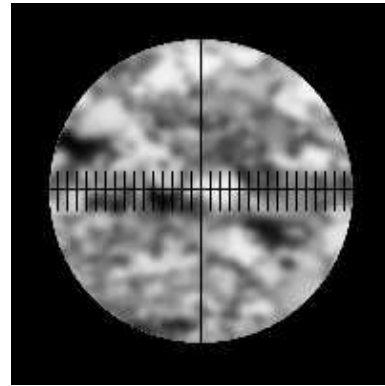
# Köhler Beleuchtung



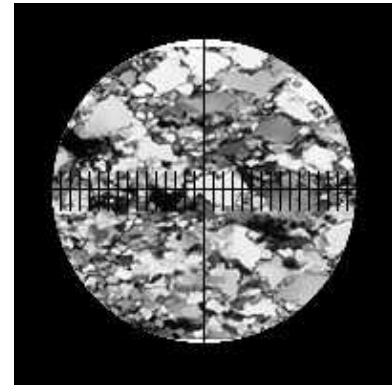
(1)



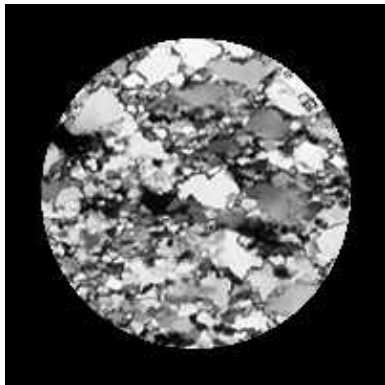
(2)



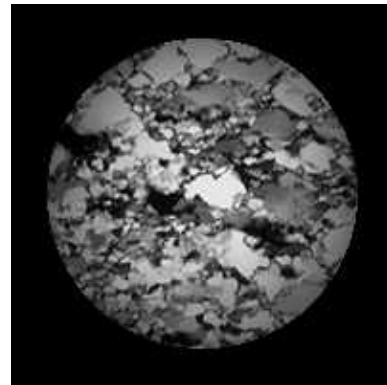
(3)



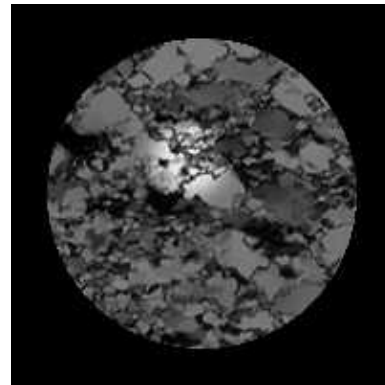
(4)



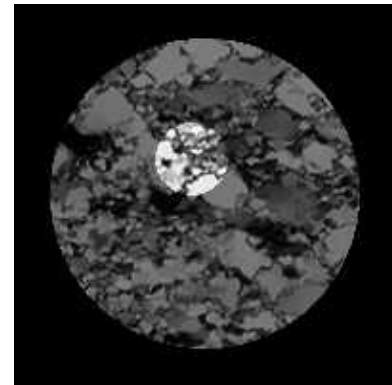
(5)



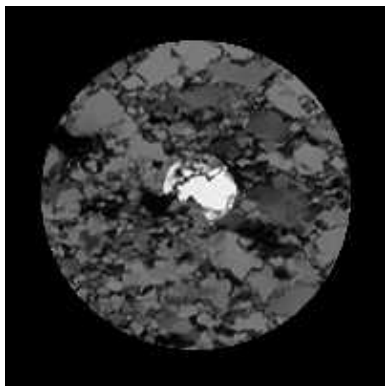
(6)



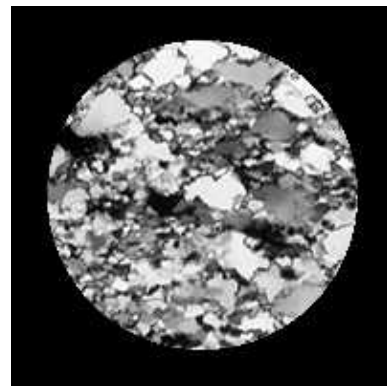
(7)



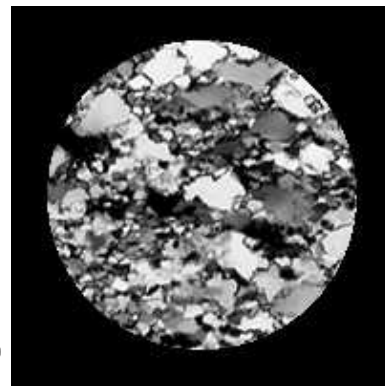
(8)



(9)



(10)



(11)

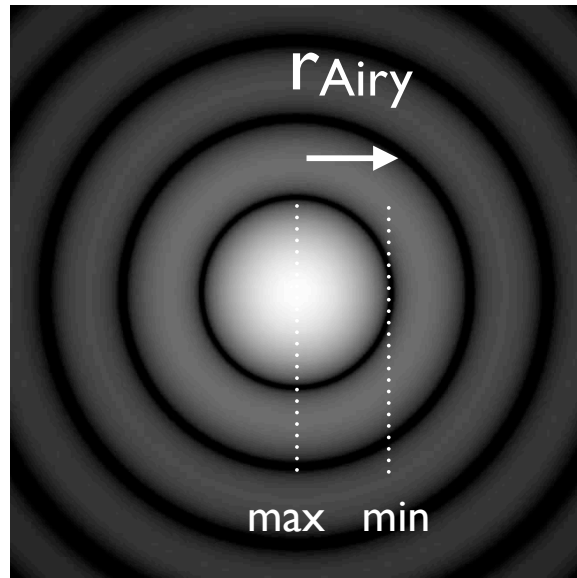
# Procedure

- (1) observe cross hair in eye piece;
- (2) focus cross hair;
- (3) observe thin section;
- (4) bring image of thin section into same plane of focus as cross hair of eyepiece;
- (5) start with well focused image;
- (6) install appropriate condenser (with numerical aperture matching that of objective) and open condenser diaphragm completely;
- (7) close illumination diaphragm;
- (8) focus image of closed diaphragm by moving the condenser up and down;
- (9) center image of illumination diaphragm using condenser screws;
- (10) open illumination diaphragm until the rim of the opening barely disappears from the field of view;
- (11) stop down condenser.



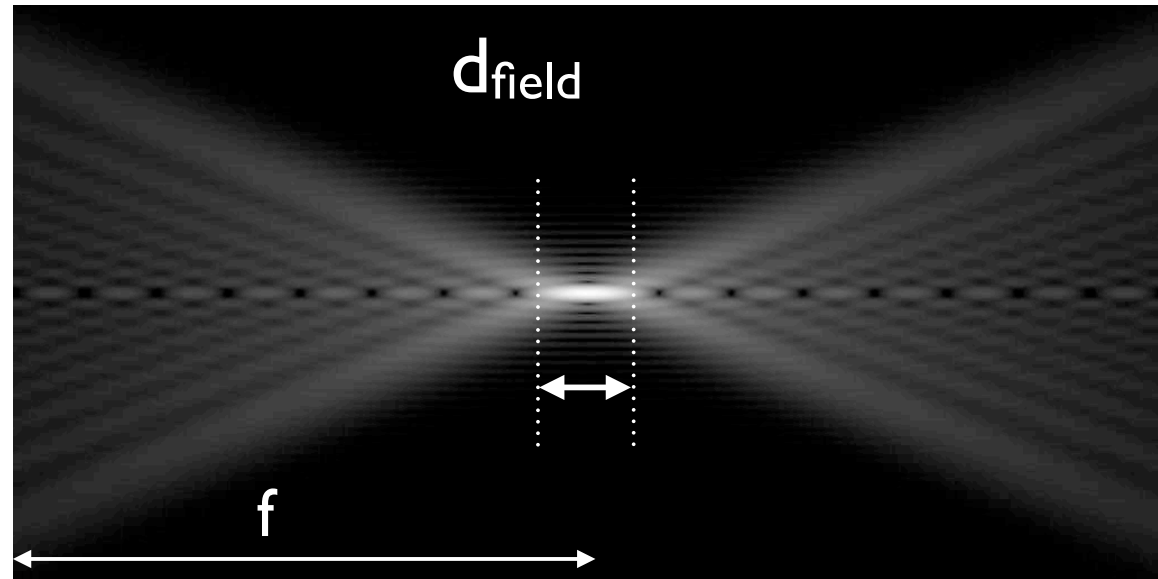
# Point spread function (PSF)

lateral resolution



$$r_{\text{Airy}} = 1.22 \cdot \lambda / (2 \cdot \text{NA})$$
$$d = 1.22 \cdot \lambda / (\text{NA}_{\text{obj}} + \text{NA}_{\text{cond}})$$
$$d \approx \lambda / \text{NA} = \lambda / (n \cdot \sin(\alpha))$$

depth resolution



$$d_{\text{field}} = \lambda / (2 \cdot n \cdot \sin^2(u))$$
$$d_{\text{field}} = \lambda / (2 \cdot \text{NA}^2)$$

intermediate magnification:  
microscope objective (10x / 0.3)  
wavelength (max. human sensitivity) = 590 nm

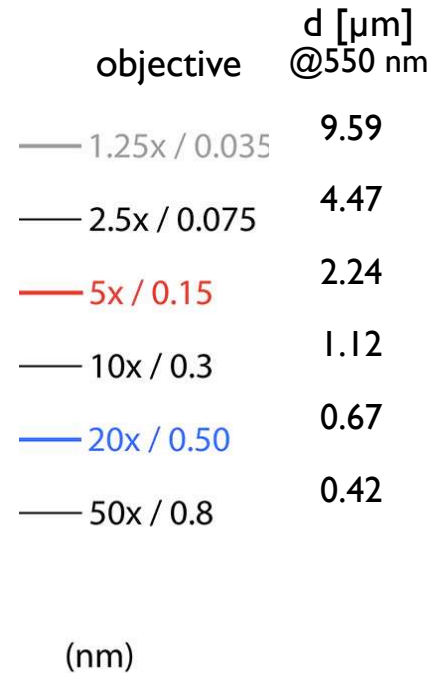
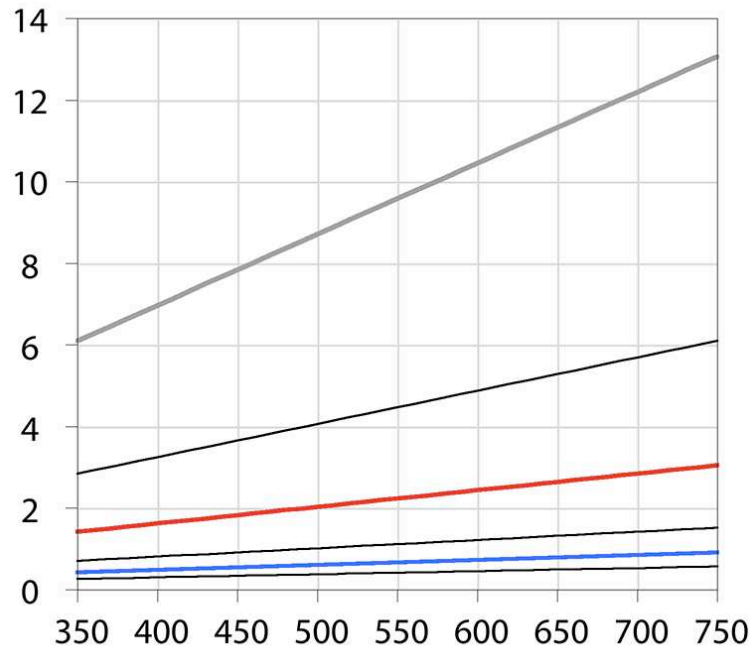
$$d = 590 \text{ nm} / 0.3 = 1.97 \text{ } \mu\text{m}$$

max. resolution of light microscope:  
objective (100x / 1.33) oil immersion  
light: near UV blue = 400 nm

$$d = 400 \text{ nm} / 1.33 = 300 \text{ nm}$$

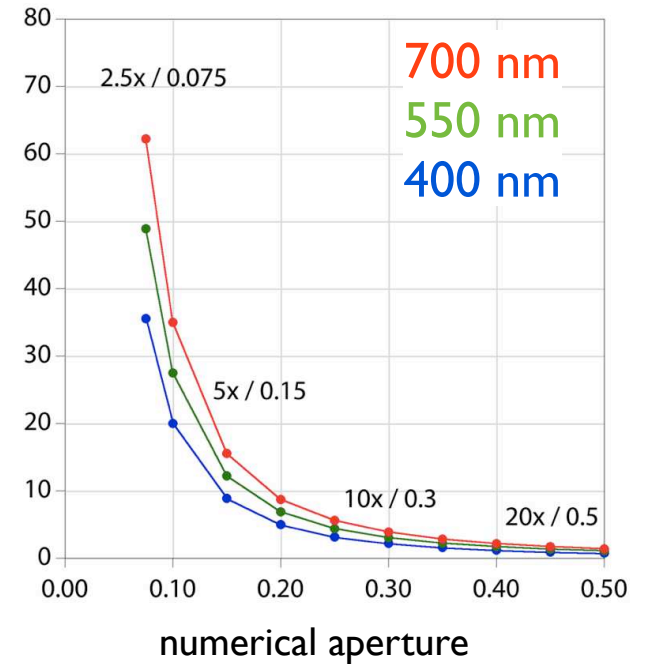
# Spatial resolution

$d$  [ $\mu\text{m}$ ]



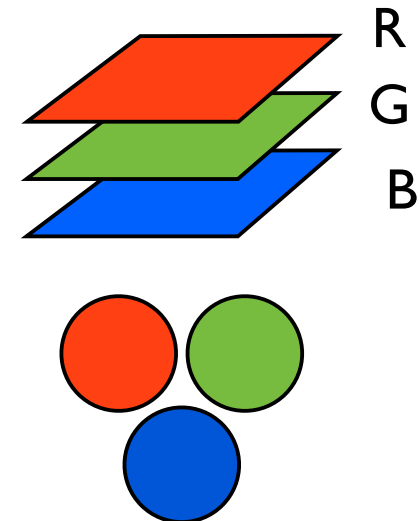
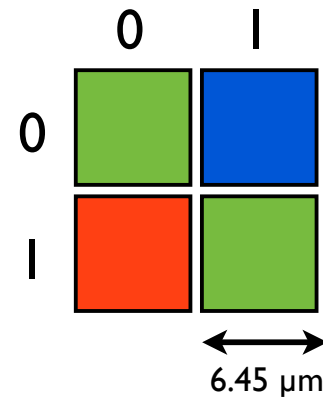
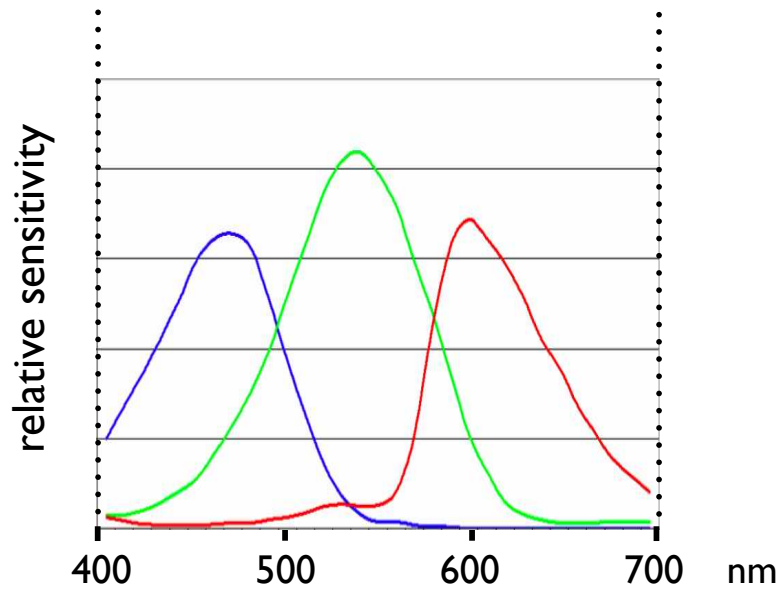
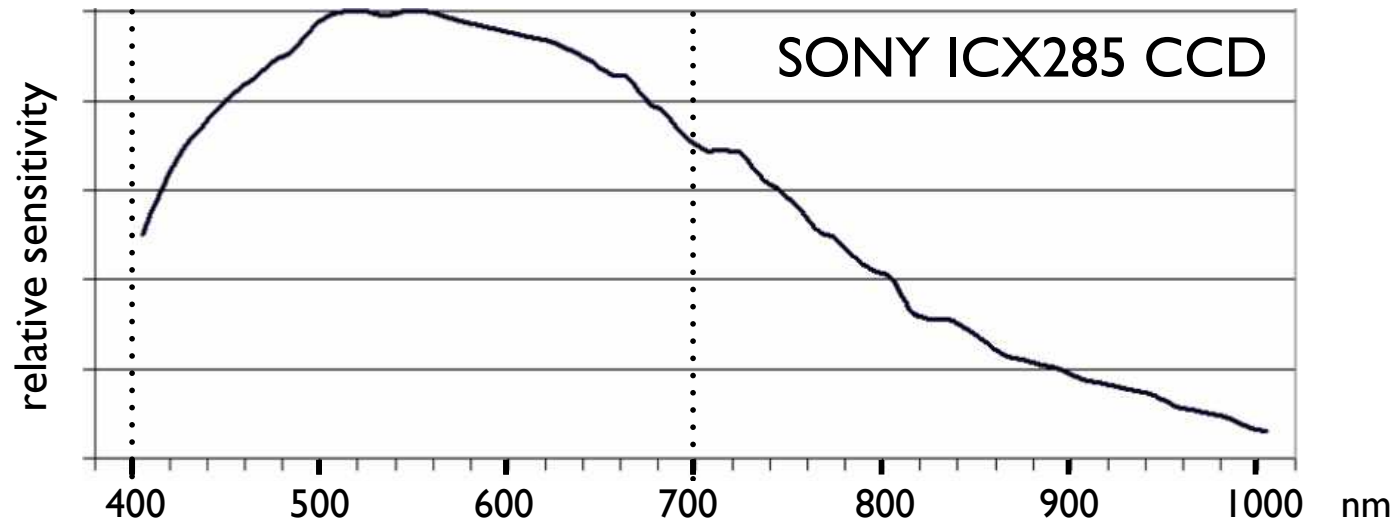
lateral resolution

$d_{\text{field}}$  [ $\mu\text{m}$ ]



depth resolution  
(depth of field)

# Image sensor





# Resolved length and size of pixel

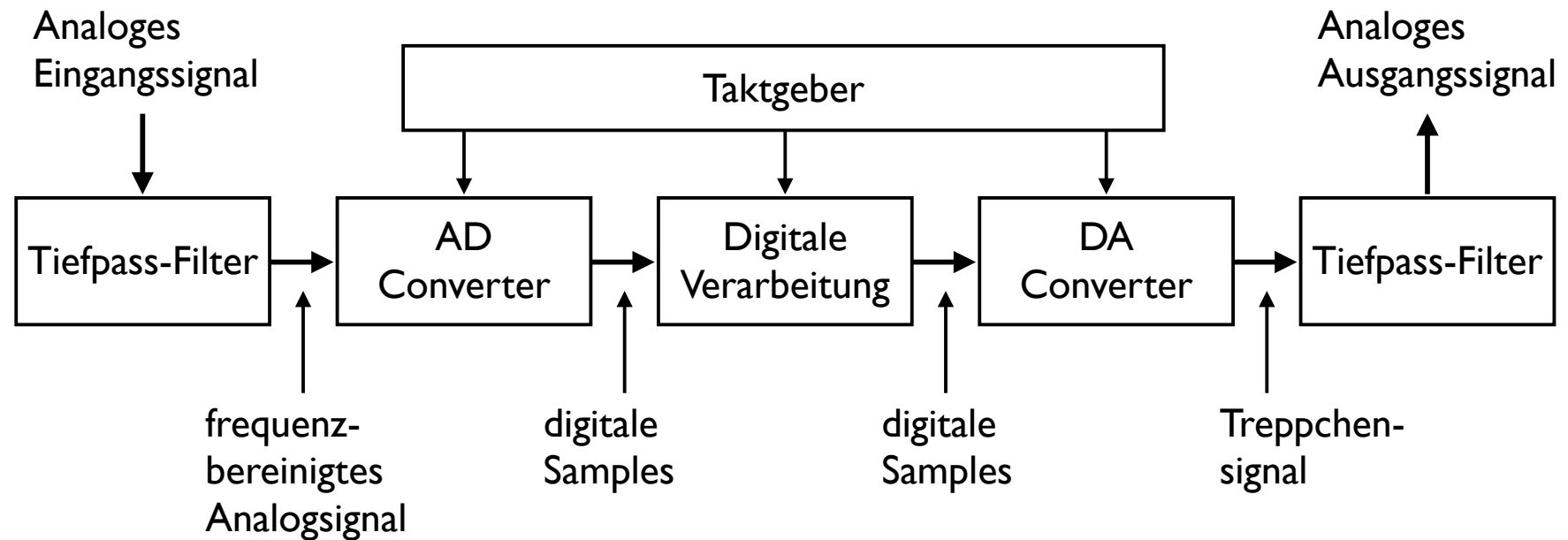
## ZEISS Axiocam mono

objective [mag. / NA]	measured length [ $\mu\text{m}$ ]	equivalent no. of pixels	size of pixel in reality [ $\mu\text{m}$ ]	optically resolved length [ $\mu\text{m}$ ]
2.5x / 0.075	500	205	2.44	4.47
5x / 0.15	100	79	1.27	2.24
10x / 0.30	100	156	0.64	1.12
20x / 0.50	50	155	0.32	0.67
50x / 0.80	20	158	0.13	0.42

Pixelgrösse < aufgelöste Distanz (d)  
Pixelgrösse  $\approx 1/2$  d

# Nyquist-Shannon Abtasttheorem

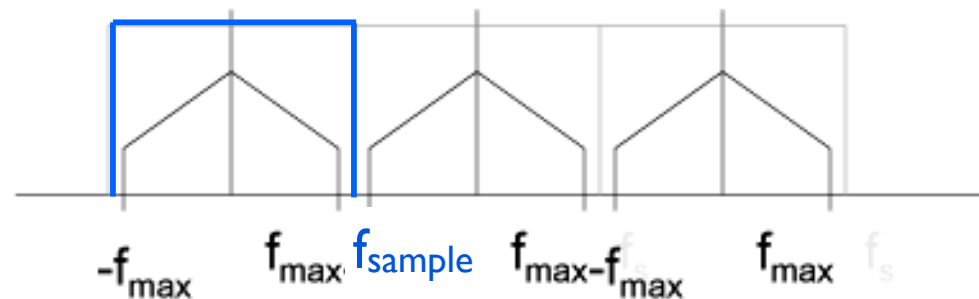
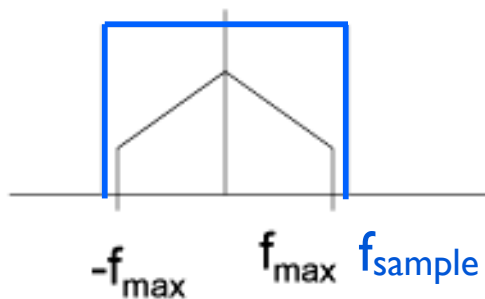
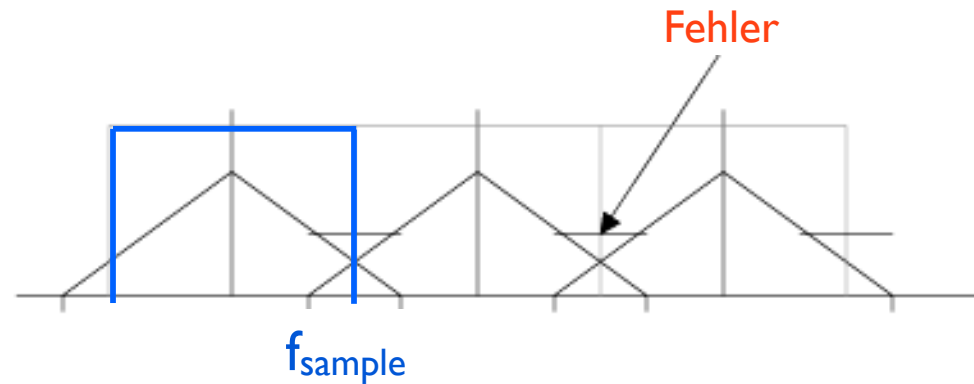
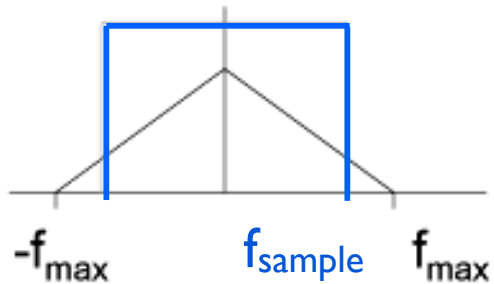
# Sampling



nach:  
Optimierung der Farbwiedergabe digitaler  
Kamerasystem (Dr. Peter R. Fornaro)



# Abtasttheorem nach Shannon, Nyquist

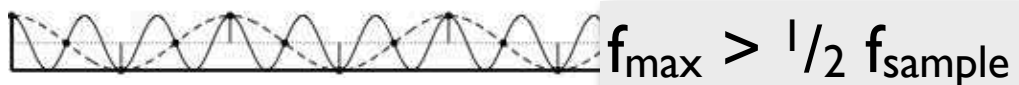


Frequenzspektrum des Ausgangssignals mit  $f_{\max}$

Frequenzspektrum des abgetasteten Signals mit  $f_{\text{sample}}$

nach:  
Optimierung der Farbwiedergabe digitaler  
Kamerasystem (Dr. Peter R. Fornaro)

# Sampling



Die Abtastfrequenz ( $f_{\text{sample}}$ ) ist in allen Teilabbildungen dieselbe.

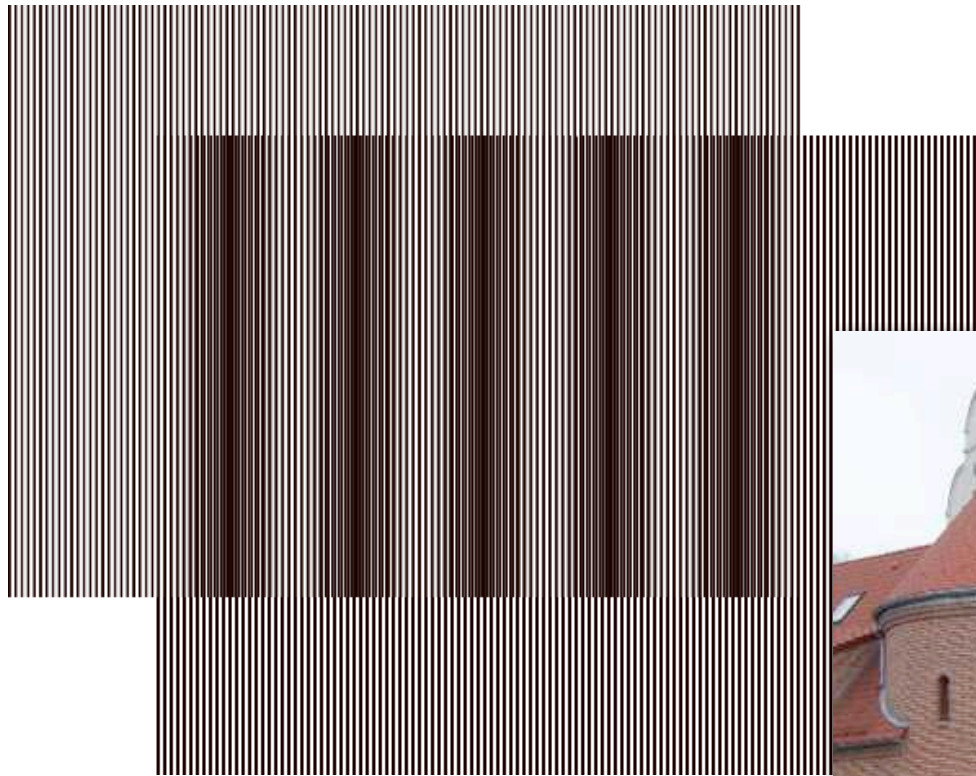
Erhöhung der Signalfrequenz:  
(über die halbe Abtastfrequenz)

Nach unten hin steigt die größte im Signal enthaltene Frequenz ( $f_{\max}$ ) an. Die gestrichelten Linien sind mögliche Signale, die (bei der vorliegenden Abtastung mit  $f_{\text{sample}}$ ) die gleichen Messpunkte hätten.

<http://de.wikipedia.org/wiki/Nyquist-Shannon-Abtasttheorem>

$$\Rightarrow f_{\text{sample}} > 2 f_{\max}$$

# Moiré - Effekt



[de.wikipedia.org/wiki/  
Moiré-Effekt#mediaviewer/  
File:Moireraster.png](https://de.wikipedia.org/wiki/Moiré-Effekt#mediaviewer/File:Moireraster.png)

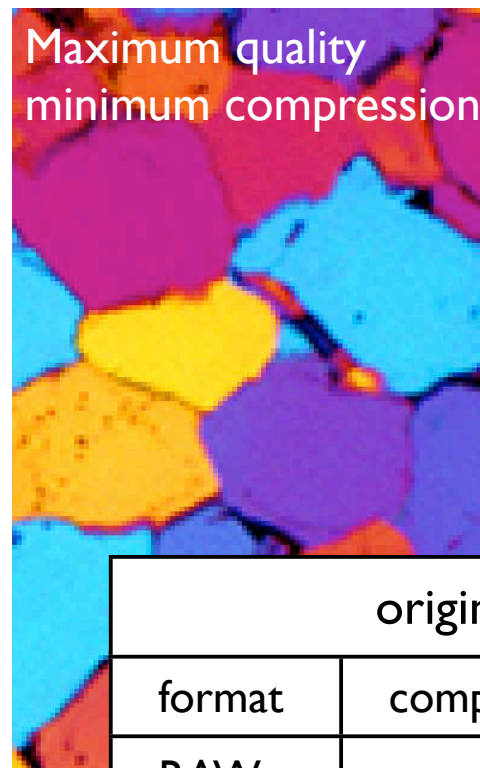
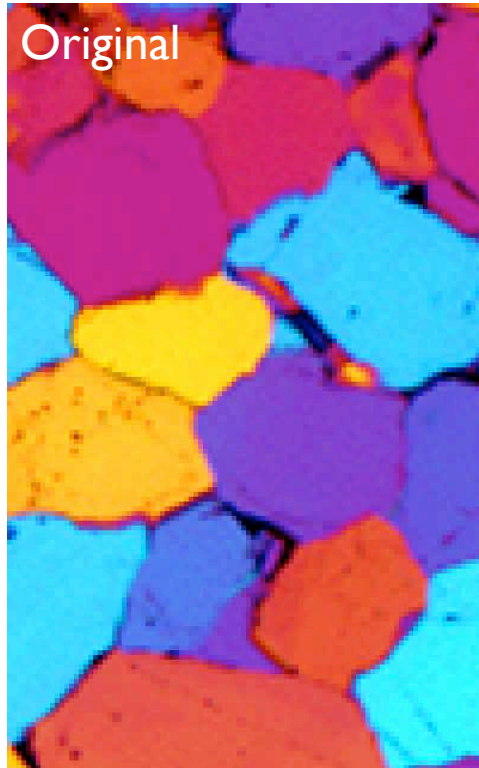


[de.wikipedia.org/wiki/Moiré-Effekt](https://de.wikipedia.org/wiki/Moiré-Effekt)



# Format & Kompression

# JPEG compression



1kB = 1000 byte 1KB = 1024 byte

The Mac OS X 10.6 file manager is a notable example of this usage in software.

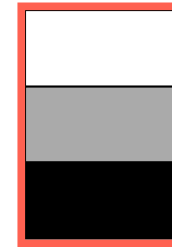
Since Snow Leopard, file sizes are reported in decimal units

<http://en.wikipedia.org/wiki/Kilobyte>

original image 900 · 600 RGB			
format	compression (mode)	type	size (bytes)
RAW	-	-	1,684,845
TIFF	-	lossless	1,688,050
TIFF	LZW	lossless	1,350,657
JPEG	max quality	lossless	195,871
JPEG	max compression	lossy	71,534
PNG	-	lossless	242,286

# Image headers: RAW and TIFF

image (8 · 12 pixel)



no header  
RAW

import - export

```
0: 0000 0000 0000 0000 0000 0000 0000 0000
10: 0000 0000 0000 0000 0000 0000 0000 0000
20: 0000 0000 0000 0000 0000 0000 0000 0000
30: 0000 0000 0000 0000 0000 0000 0000 0000
40: FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF
50: FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF
60:
70:
80:
90:
A0:
B0:
C0:
D0:
```

with header

TIFF, TIF

(tagged image file (format))

open - save

```
0: 4D 40 002A 0000 0008 000A 00FE 0004 0000
10: 0001 0000 0000 0100 0003 0000 0001 0008
20: 0000 0101 0003 0000 0001 000C 0000 0102
30: 0003 0000 0001 0008 0000 0106 0003 0000
40: 0001 0000 0000 0111 0004 0000 0001 0000
50: 0300 0115 0003 0000 0001 0001 0000 0116
60: 0003 0000 0001 000C 0000 0117 0004 0000
70: 0001 0000 0050 A932 0003 0000 0100 0000
80: 0100 0000 0000 0000 0000 0000 0000 0000
90: 0000 0000 0000 0000 0000 0000 0000 0000
A0: 0000 0000 0000 0000 0000 0000 0000 0000
B0: 0000 0000 0000 0000 0000 0000 0000 0000
C0: 0000 0000 0000 0000 0000 0000 0000 0000
D0: 0000 0000 0000 0000 0000 0000 0000 0000
E0: 0000 0000 0000 0000 0000 0000 0000 0000
F0: 0000 0000 0000 0000 0000 0000 0000 0000
100: 4950 4943 4940 4147 000C 0008 00A2 0300
110: 0000 0000 0000 0000 0000 0000 0000 0000
120: 0000 0000 0000 0000 0000 0000 0000 0000
130: 0000 0000 0000 0000 0000 0000 0000 0000
270: 0000 0000 0000 0000 0000 0000 0000 0000
280: 0000 0000 0000 0000 0000 0000 0000 0000
290: 0000 0000 0000 0000 0000 0000 0000 0000
2A0: 0000 0000 0000 0000 0000 0000 0000 0000
2B0: 0000 0000 0000 0000 0000 0000 0000 0000
2C0: 0000 0000 0000 0000 0000 0000 0000 0000
2D0: 0000 0000 0000 0000 0000 0000 0000 0000
2E0: 0000 0000 0000 0000 0000 0000 0000 0000
2F0: 0000 0000 0000 0000 0000 0000 0000 0000
300: 0000 0000 0000 0000 0000 0000 0000 0000
310: 0000 0000 0000 0000 0000 0000 0000 0000
320: 0000 0000 0000 0000 0000 0000 0000 0000
330: 0000 0000 0000 0000 0000 0000 0000 0000
340: FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF
350: FFFF FFFF FFFF FFFF FFFF FFFF FFFF FFFF
360:
```



# TIFF

## Tagged Images File Format

Das Tagged Images File Format (TIFF) besteht aus

- (1) Image File Header (IFH).
- (2) Liste von Image File Directories (IFD). Die Zeiger ... enthalten Informationen zu Größe, Auflösung, etc. der Bilder.
- (3) Variablen Anzahl von Datenblöcken

## Tools

Hexdump:

ExifTool-9.71.dmg ([www.sno.phy.queensu.ca/~phil/exiftool/html/dump.html](http://www.sno.phy.queensu.ca/~phil/exiftool/html/dump.html))

Convert ASCII - hexadecimal - decimal - binary:  
[www.rapidtables.com/convert/number/index.htm](http://www.rapidtables.com/convert/number/index.htm)

IFH	IFD0	Data0
IFD0	Data0	Data1
IFD1	IFD1	Data2
IFD2	Data1	IFD0
Data0	IFD2	IFD1
Data1	Data2	IFD2
Data2		

Variable Anordnung von IFH, IFD und ID

## ExifTool by Phil Harvey

Read, Write and Edit Meta Information!

Also available --> [Utility to fix Nikon NEF images corrupted by Nikon software](#)

Installing	Tag Names	Resources	History	Forum	FAQ
------------	-----------	-----------	---------	-------	-----

[Download Version 9.71 \(3.7 MB\) - Sept 20, 2014](#)

ExifTool is a platform-independent Perl library plus a command-line application for reading, writing and editing meta information in a wide variety of files. ExifTool supports many different metadata formats including EXIF, GPS, IPTC, XMP, JFIF, GeoTIFF, ICC Profile, Photoshop IRB, FlashPix, AFOP and ID3, as well as the maker notes of many digital cameras by Canon, Casio, FLIR, FujiFilm, GE, HP, JVC/Victor, Kodak, Leaf, Minolta/Konica-Minolta, Nikon, Nintendo, Olympus/Epson, Panasonic/Leica, Pentax/Asahi, Phase One, Reconyx, Ricoh, Samsung, Sanyo, Sigma/Foveon and Sony.

ExifTool is also available as a stand-alone Windows executable and a Macintosh OS X package: (Note that these versions contain the executable only, and do not include the HTML documentation or other files of the full distribution above.)

Windows Executable: [exiftool-9.71.zip \(3.7 MB\)](#)

The stand-alone Windows executable does not require Perl. Just download and un-zip the archive then double-click on "exiftool(-k).exe" to read the application documentation, drag-and-drop files and folders to view meta information, or rename to "exiftool.exe" for command-line use. Runs on all versions of Windows (including Windows 7).

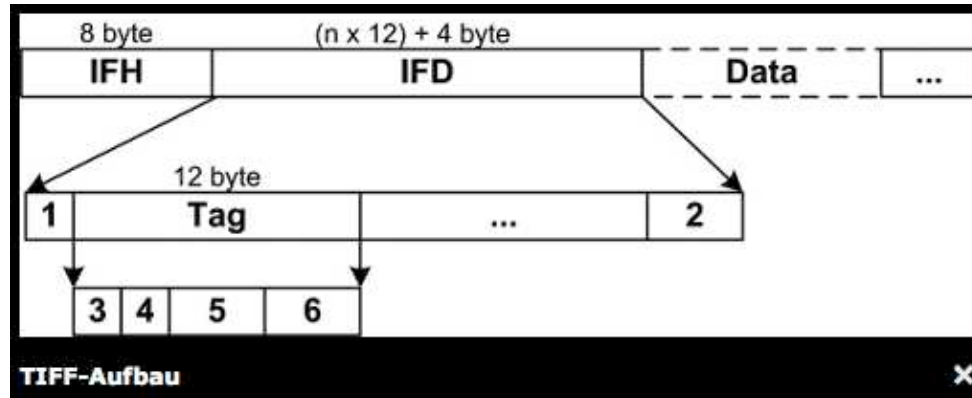
Mac OS X Package: [ExifTool-9.71.dmg \(2.4 MB\)](#)

The OS X package installs the ExifTool command-line application and libraries in /usr/bin. After installing, type "exiftool" in a Terminal window to run exiftool and read the application documentation.

Read the [installation instructions](#) for help installing ExifTool on Windows, Mac OS X and Unix systems.

[Features](#)  
[User Comments](#)  
[Supported File Types](#)  
[System Requirements](#)  
[Running ExifTool](#)  
[Example Output](#)  
[Tag Names Explained](#)  
[Tag Groups](#)  
[Writing Information](#)  
[Writer Limitations](#)  
[Known Problems](#)  
[Security Issues](#)  
[Date/Time Shift](#)  
[Renaming Files](#)  
[Performance](#)  
[ExifTool Library](#)  
[Additional Resources](#)  
[New Discoveries](#)  
[Acknowledgements](#)  
[License](#)  
[Donate](#)  
[Contact Me](#)

# Image File Header



## Image File header

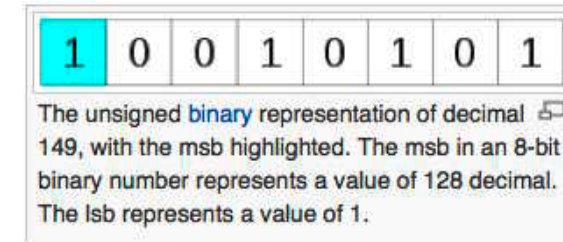
Der Image File header (IFH) ist 8 byte groß.  
Inhalt::

(1) Byteanordnung (2 byte): Bei "Little Endian" (ASCII: "II", hexadezimal: "49 49") werden die Bytes vom unbedeutendsten - least significant (links) - zum wichtigsten Byte - most significant (rechts) - hin angeordnet. Little Endian ist typisch für INTEL-basierte Betriebssysteme.

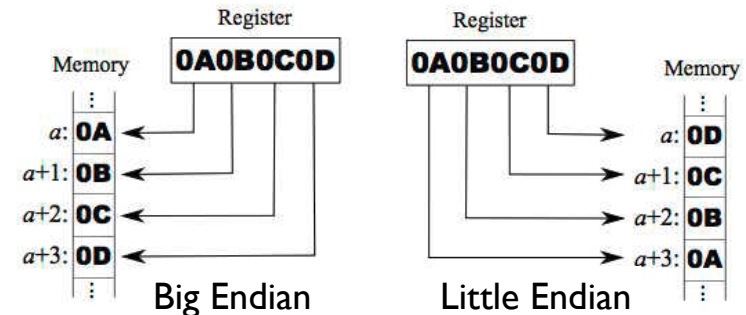
(2) Versionsnummer hexadezimal "2A" = dezimal "42" (2 Byte)

(3) Zeiger auf die Anfangsposition des ersten Image File Directory der TIFF-Datei (4 Byte).

Bit order im Byte: LSB 0 = least significant bit links; MSB 0 = most significant bit links



Byte order in 32 bit word (Endianness)



# Übung 3 : Bildformate

Struktur von TIFF header kennen lernen

■ Im Folder 'hexdump':

Die beiden Bilder u4.tif und u4R.tif in Image SXM öffnen:

Wie gross sind sie (Länge, Breite)? Welche Grauwerte kommen vor? Welche LUT ist aktiv ?

■ Im Folder 'hexdump':

Die beiden text files u4.html, uR.html in Browser (Firefox) öffnen - sie zeigen den Header der beiden Bilder u4.tif und u4R.tif.

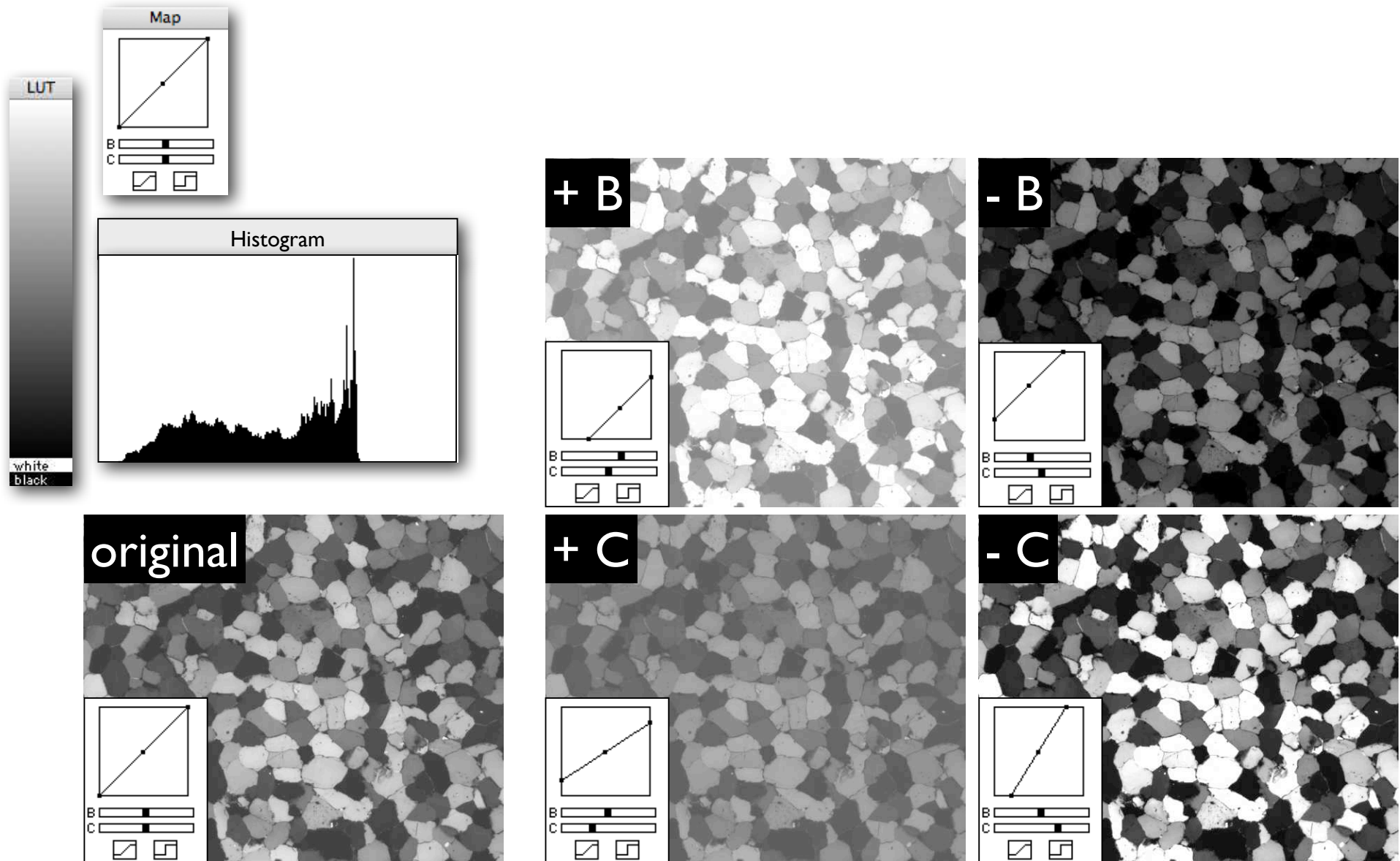
Was steht im Header. Wo sind die Bilddaten ? Vergleichen Sie den Text der Header mit dem Aussehen der Bilder.

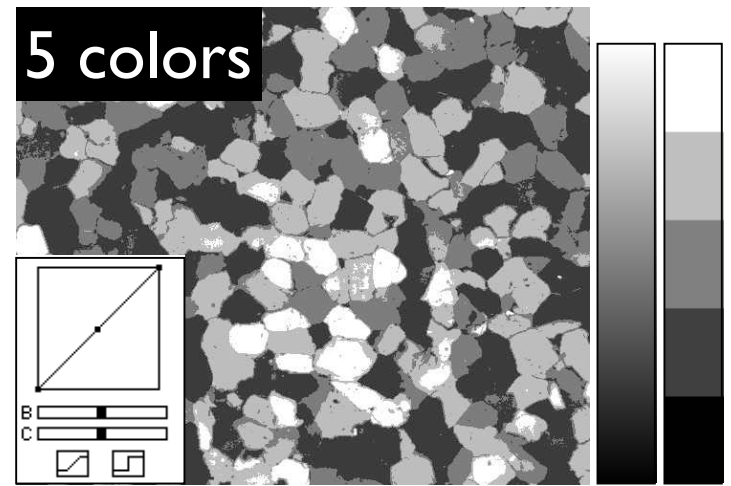
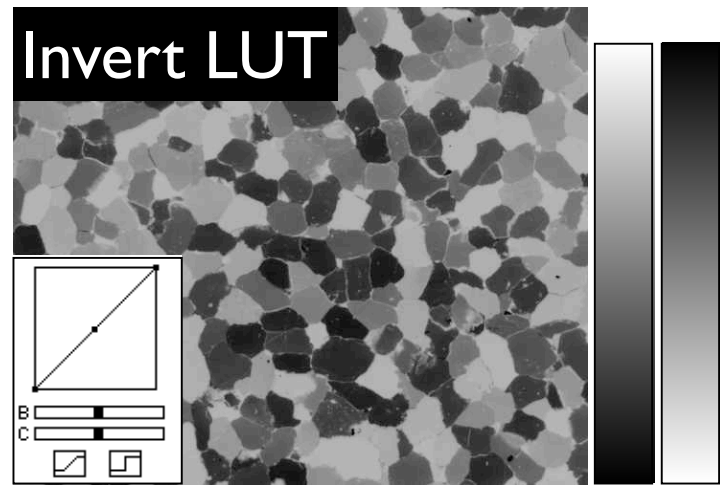
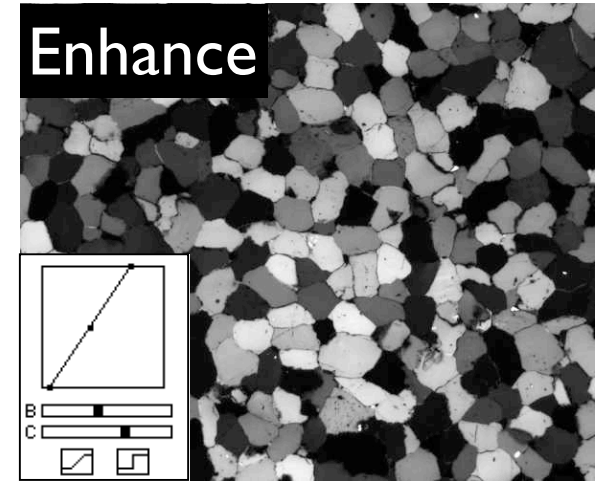
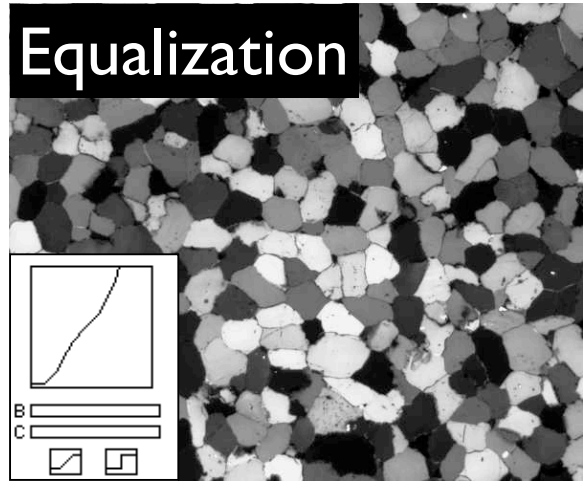
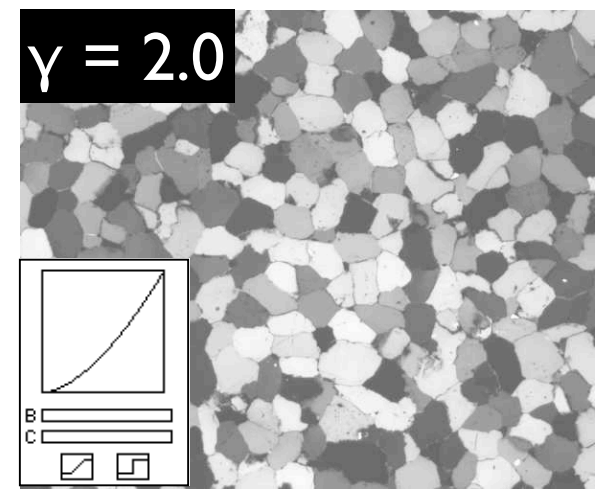
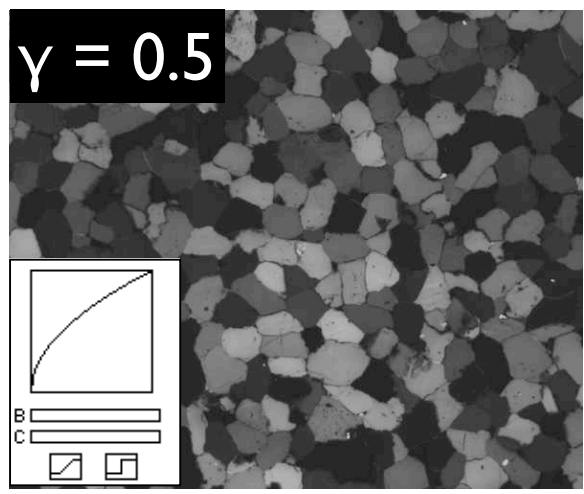
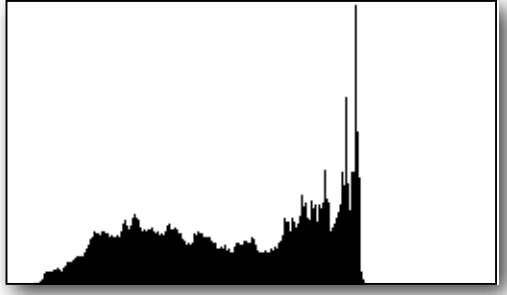
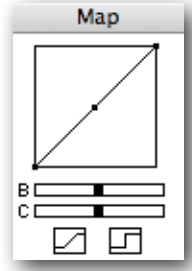




**contrast**

# Brightness Contrast

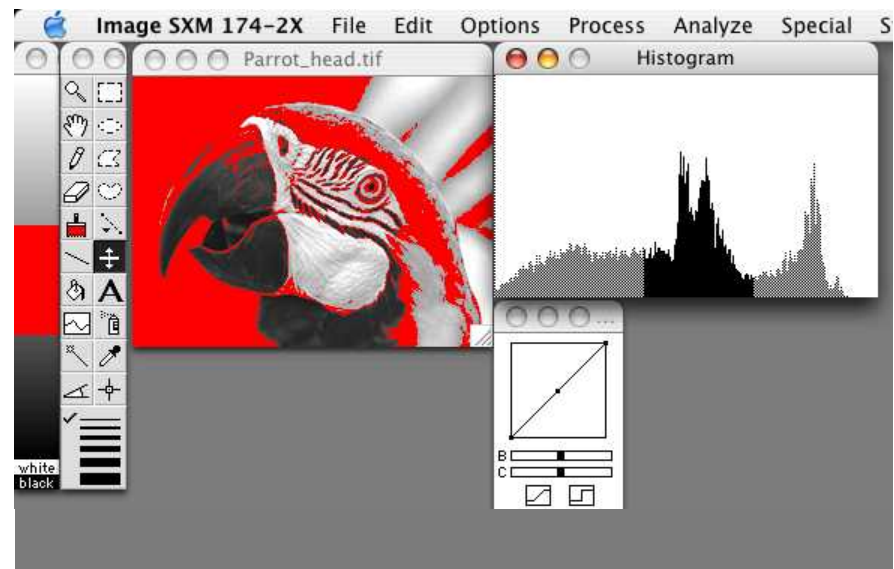
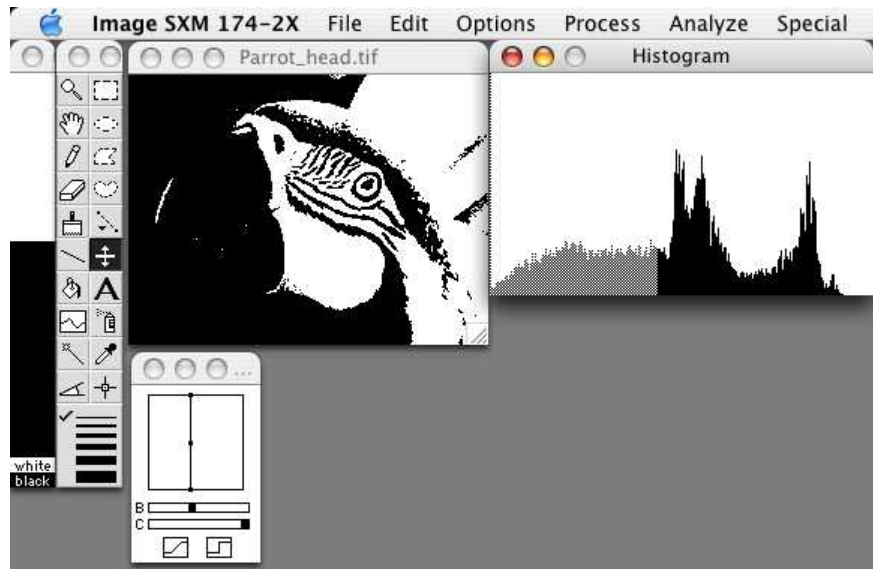
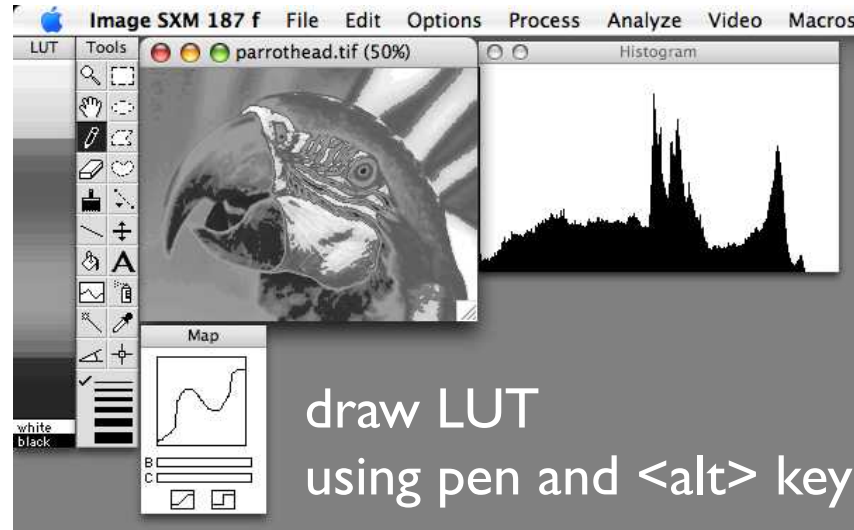






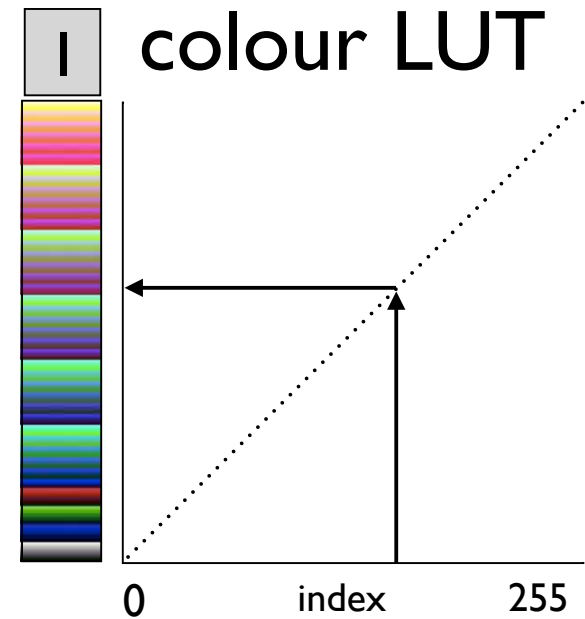
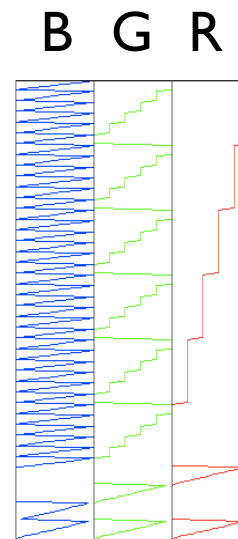
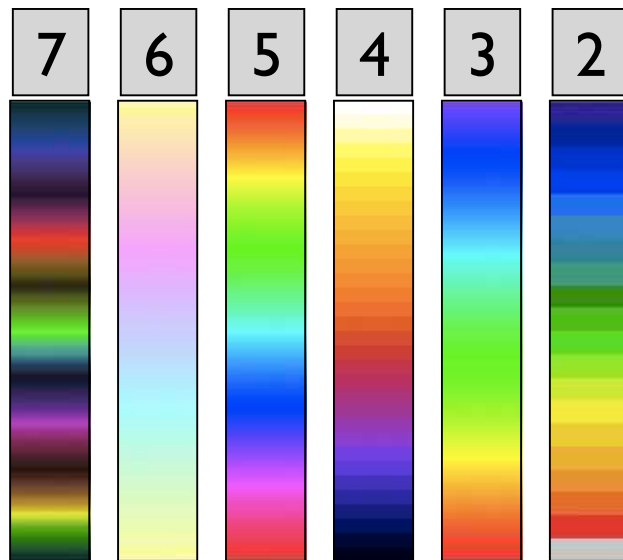
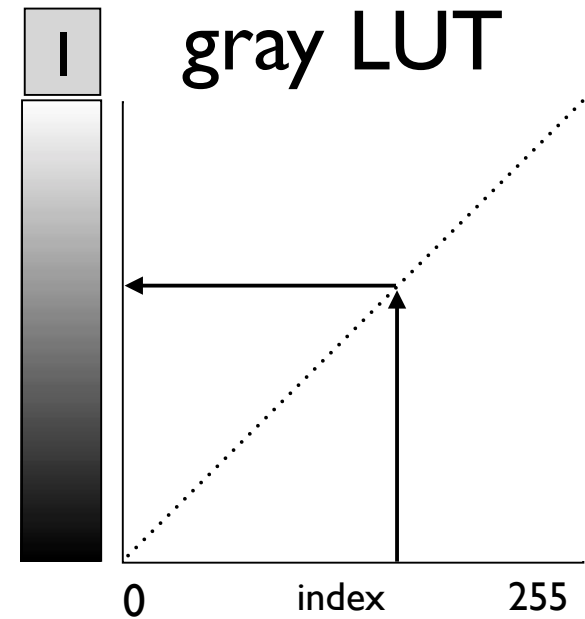
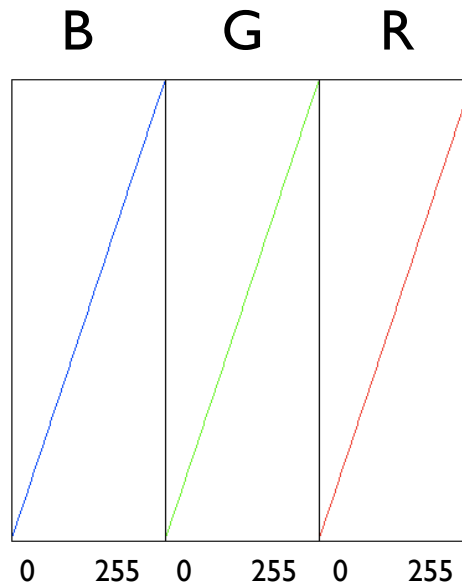
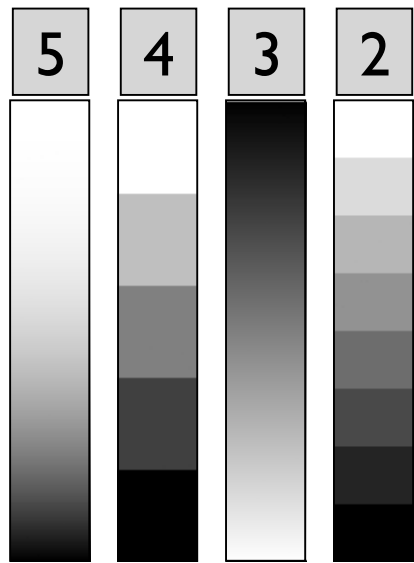
# using Map

## Custom LUT - Thresholding & Grey level slicing



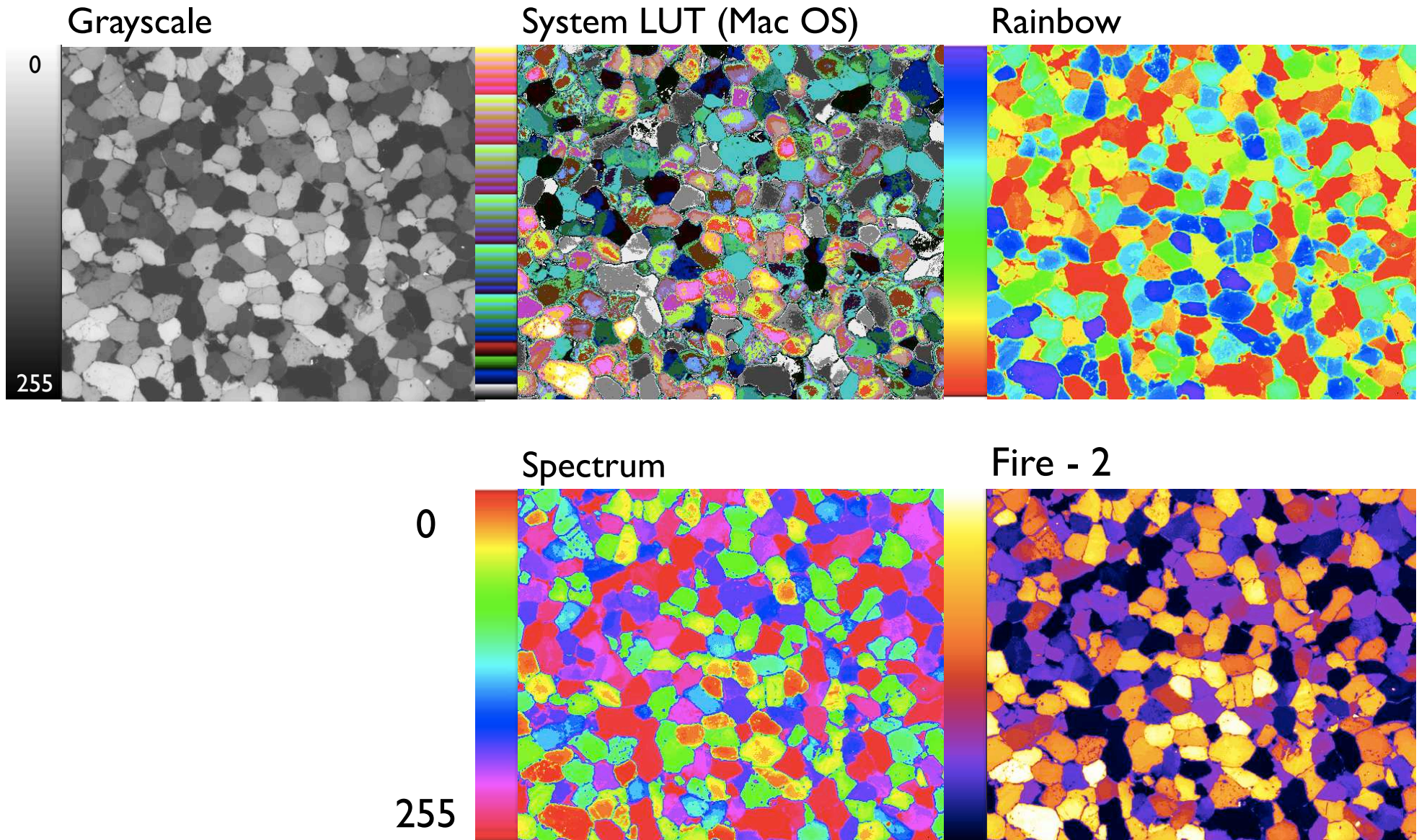
**LUTs**

# Look-Up Tables (LUT)

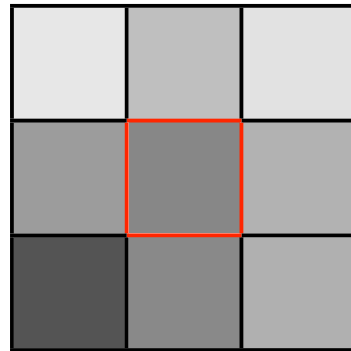
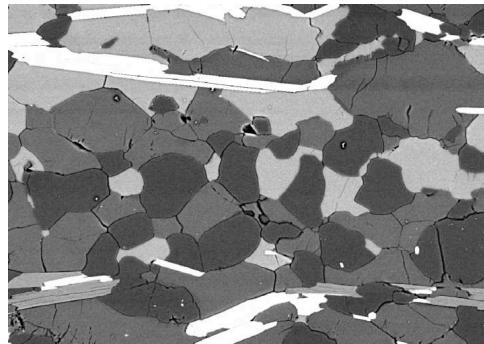




# Effect of LUT

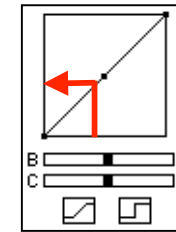


# from LUT to POP

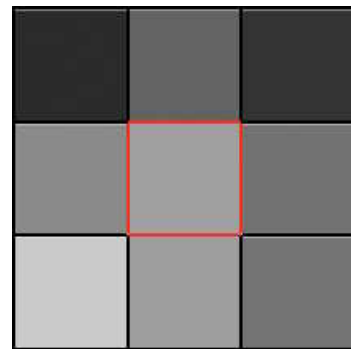
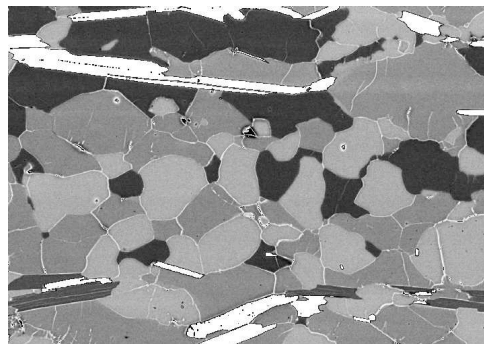


33	45	36
70	100	64
180	103	72

1:1



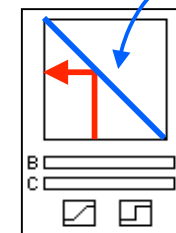
view with LUT = 1:1  
original image matrix



33	45	36
70	100	64
180	103	72

LUT

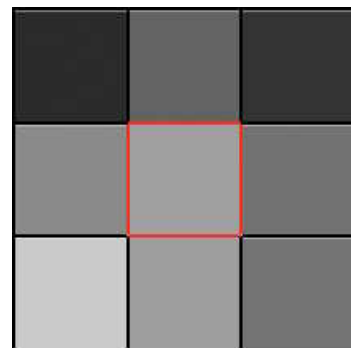
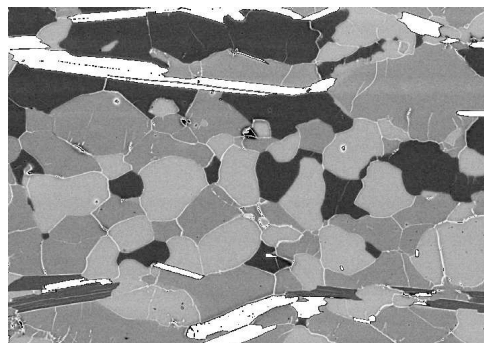
$$GV_{\text{new}} = 255 - GV_{\text{old}}$$



view with LUT inverted  
original image matrix

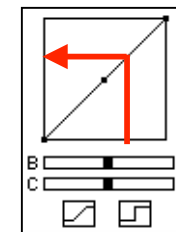


Apply LUT: ⌘L



222	210	219
185	155	191
70	152	183

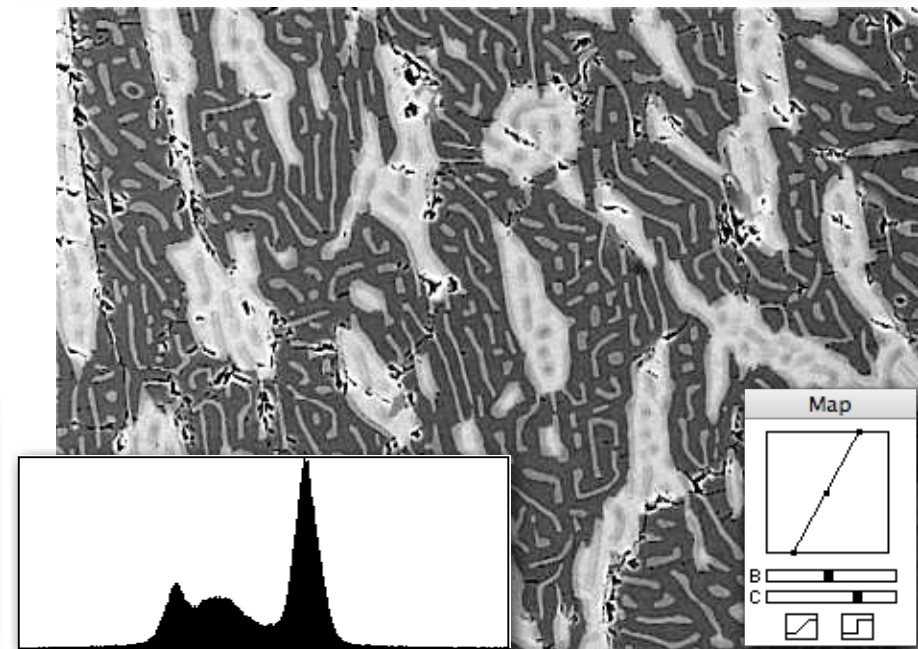
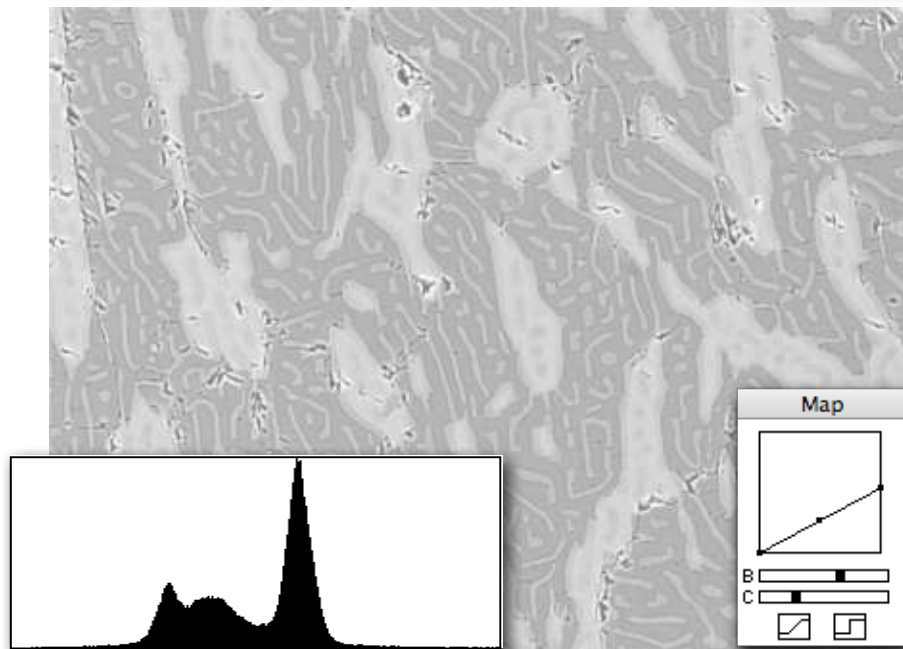
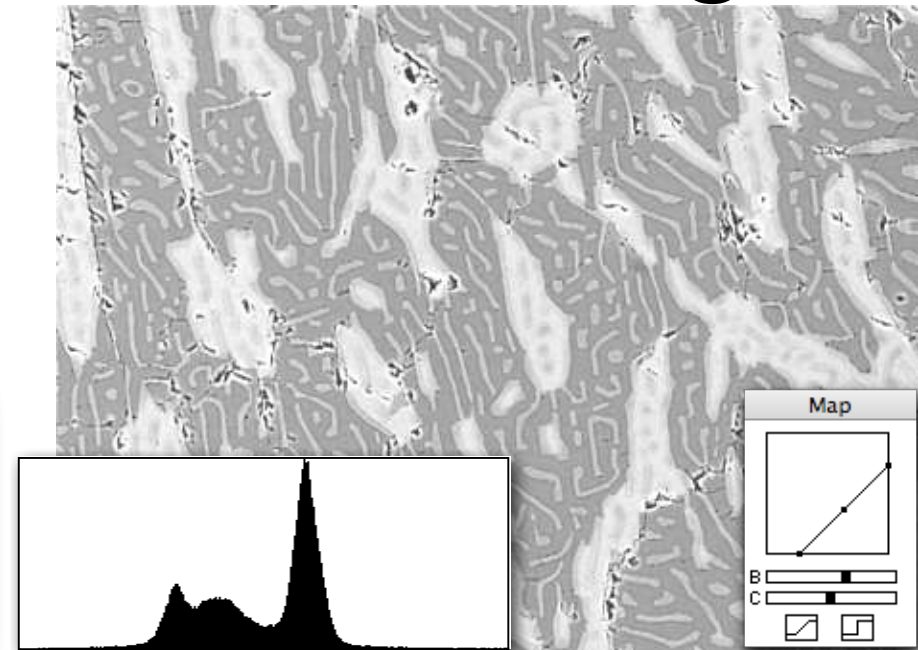
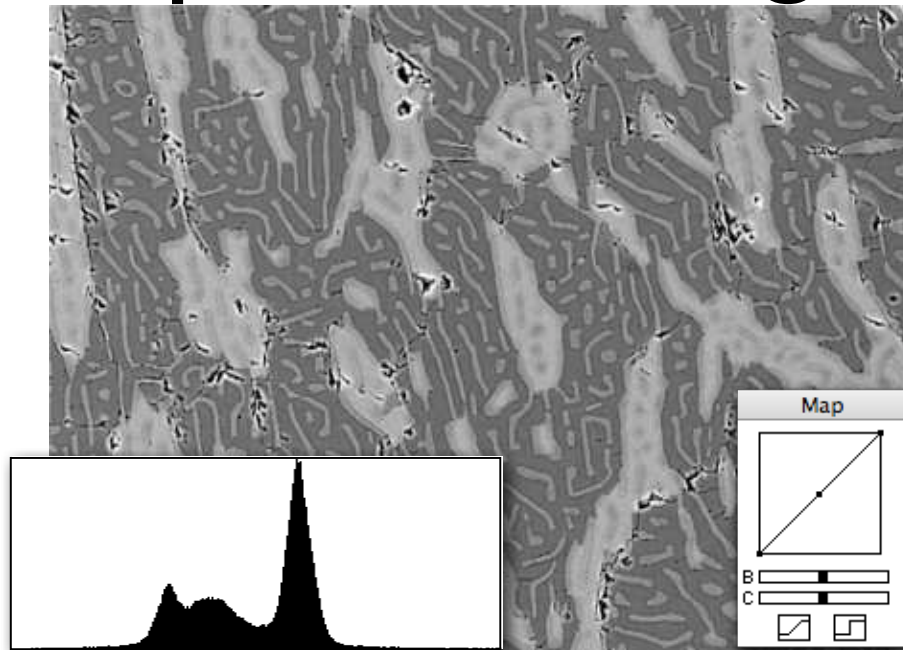
⌘L



view with LUT = 1:1  
image matrix is changed

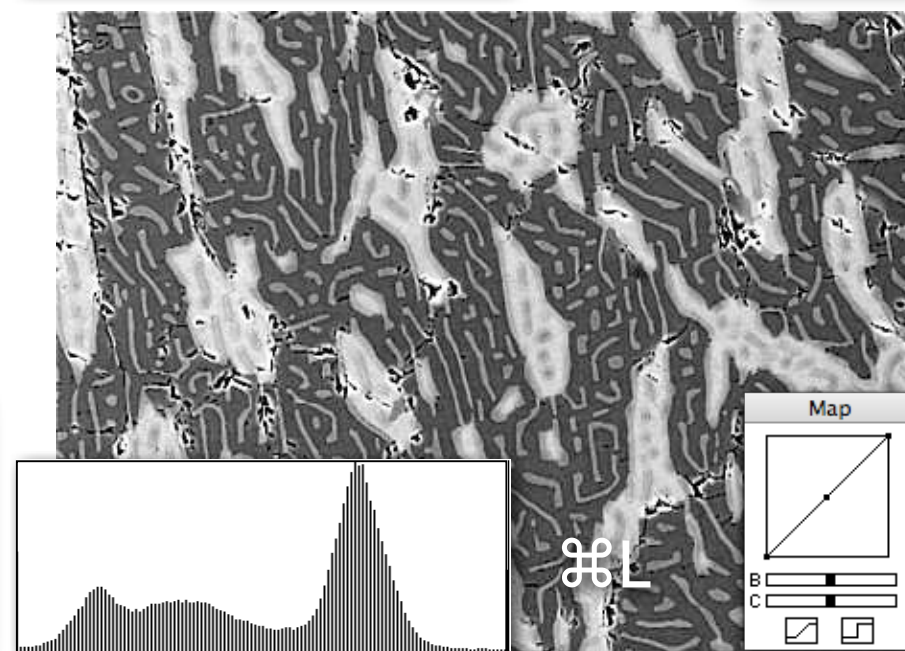
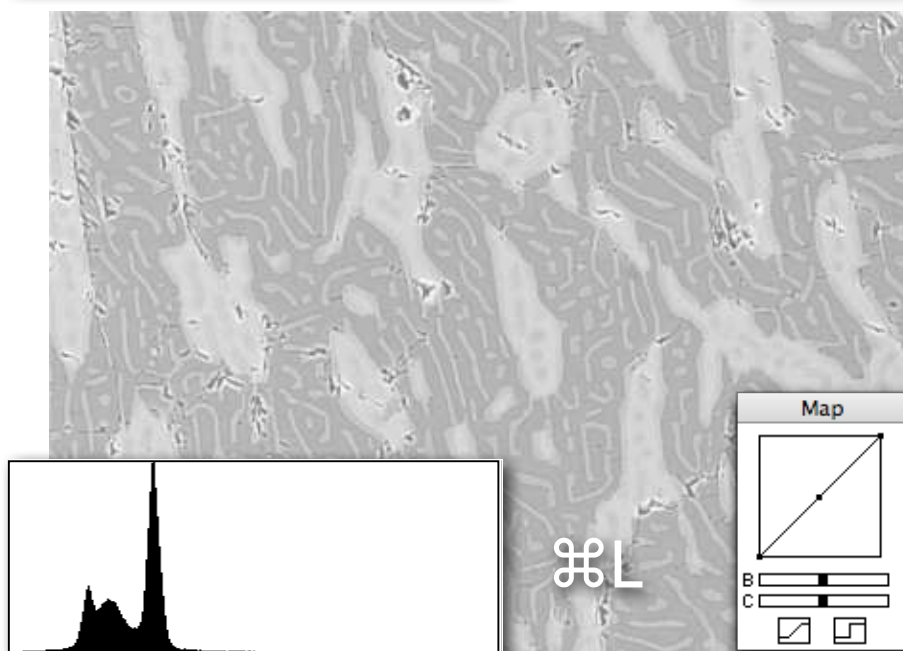
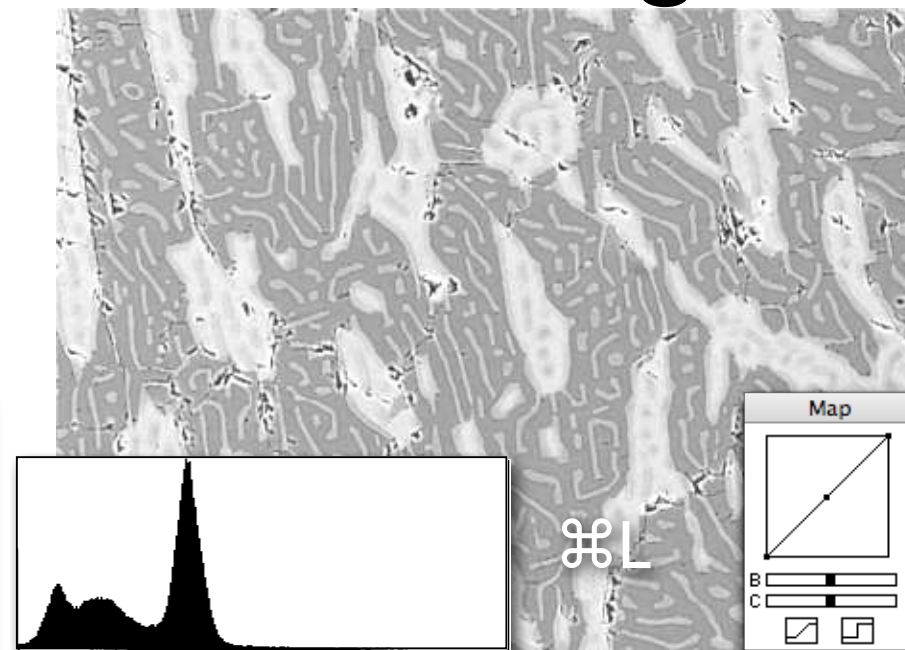
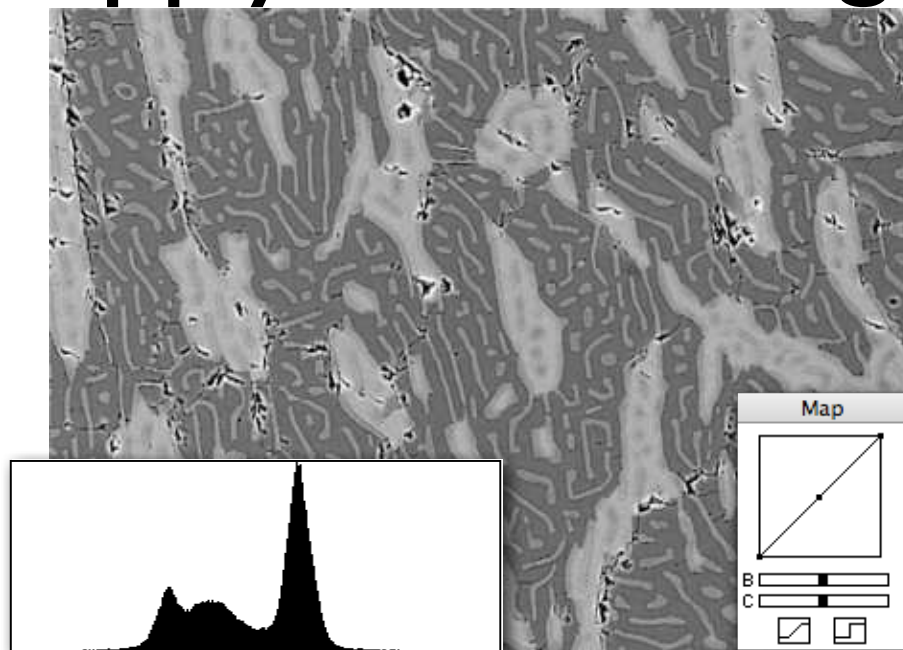


# Map/LUT - image matrix unchanged

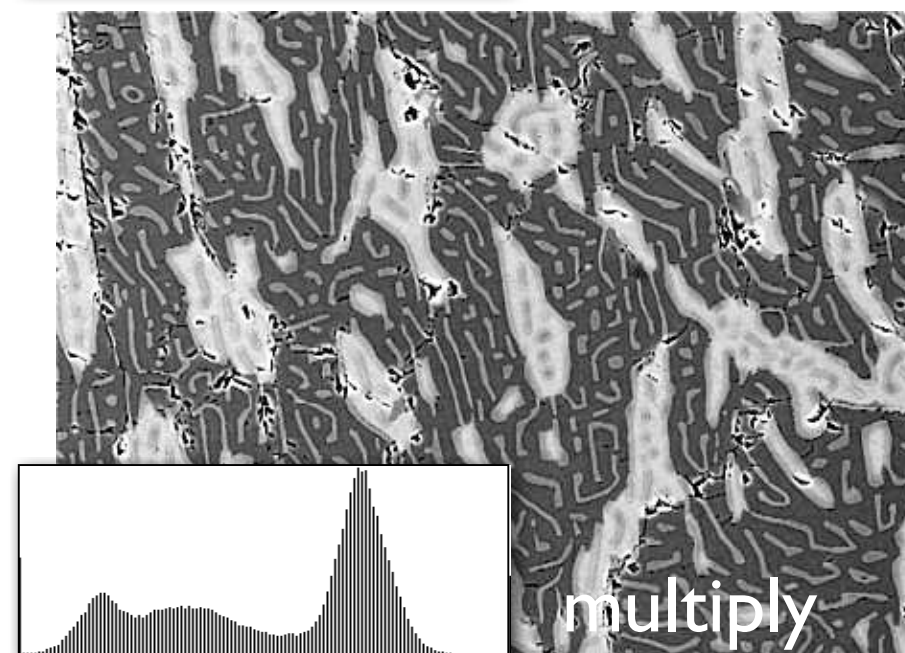
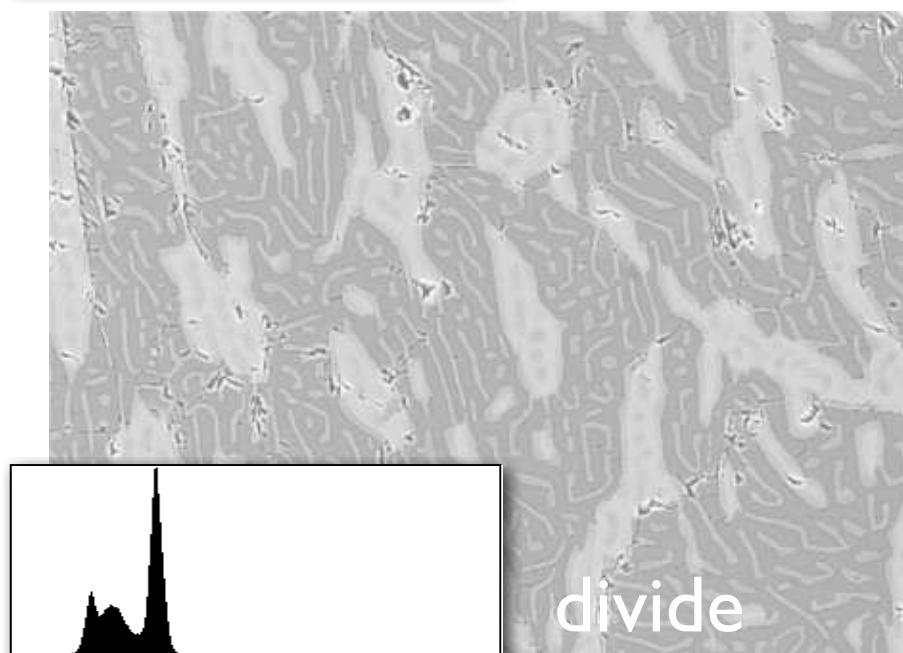
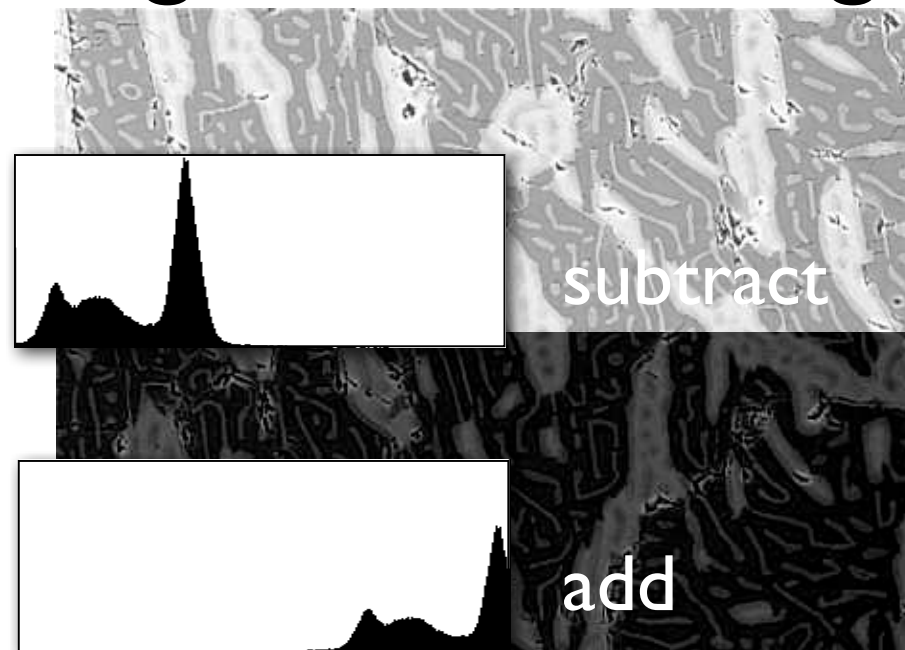
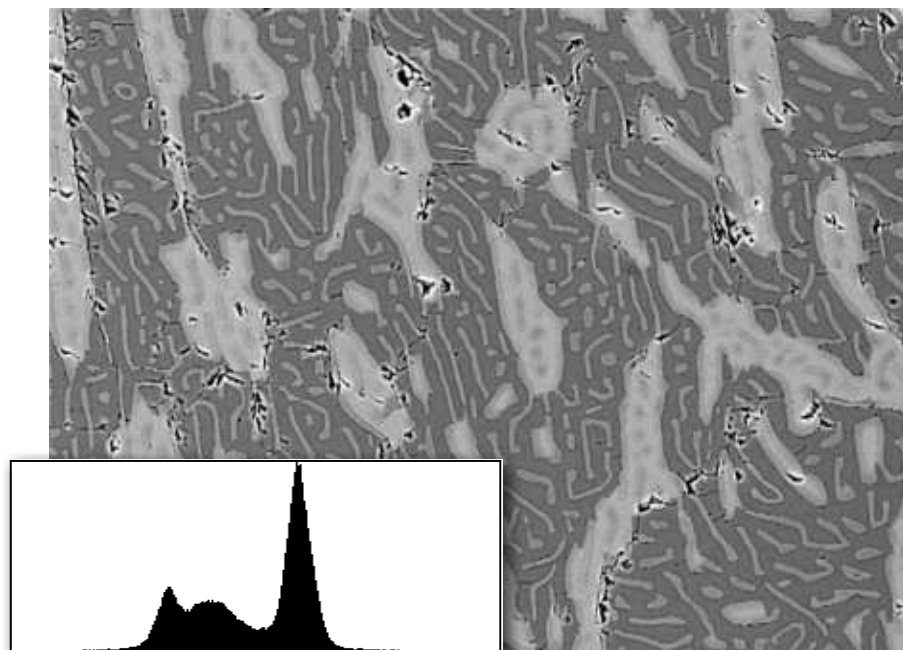




# Apply LUT - image matrix changed



# Arithmetic POP - image matrix changed



**macros**



# Lazy LUT macro



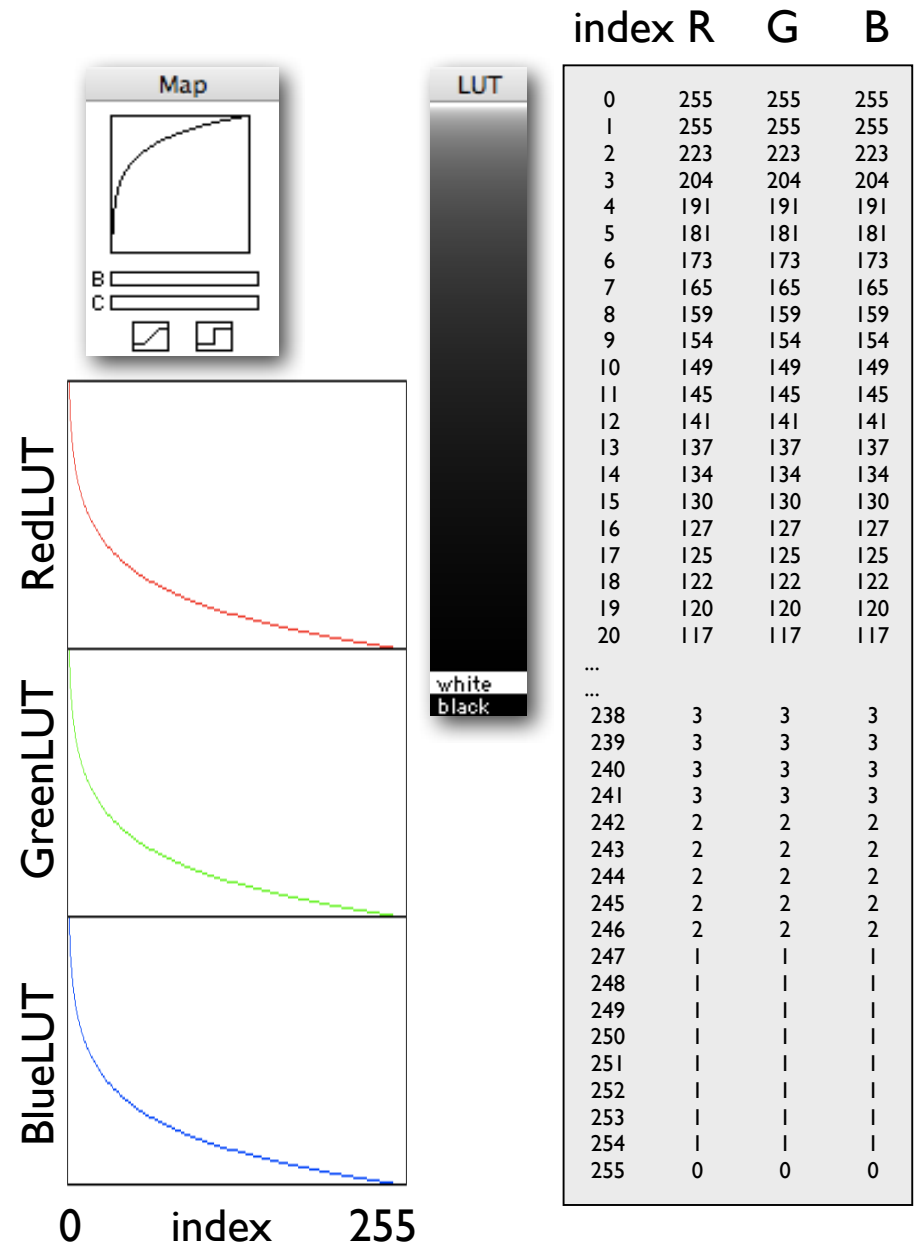
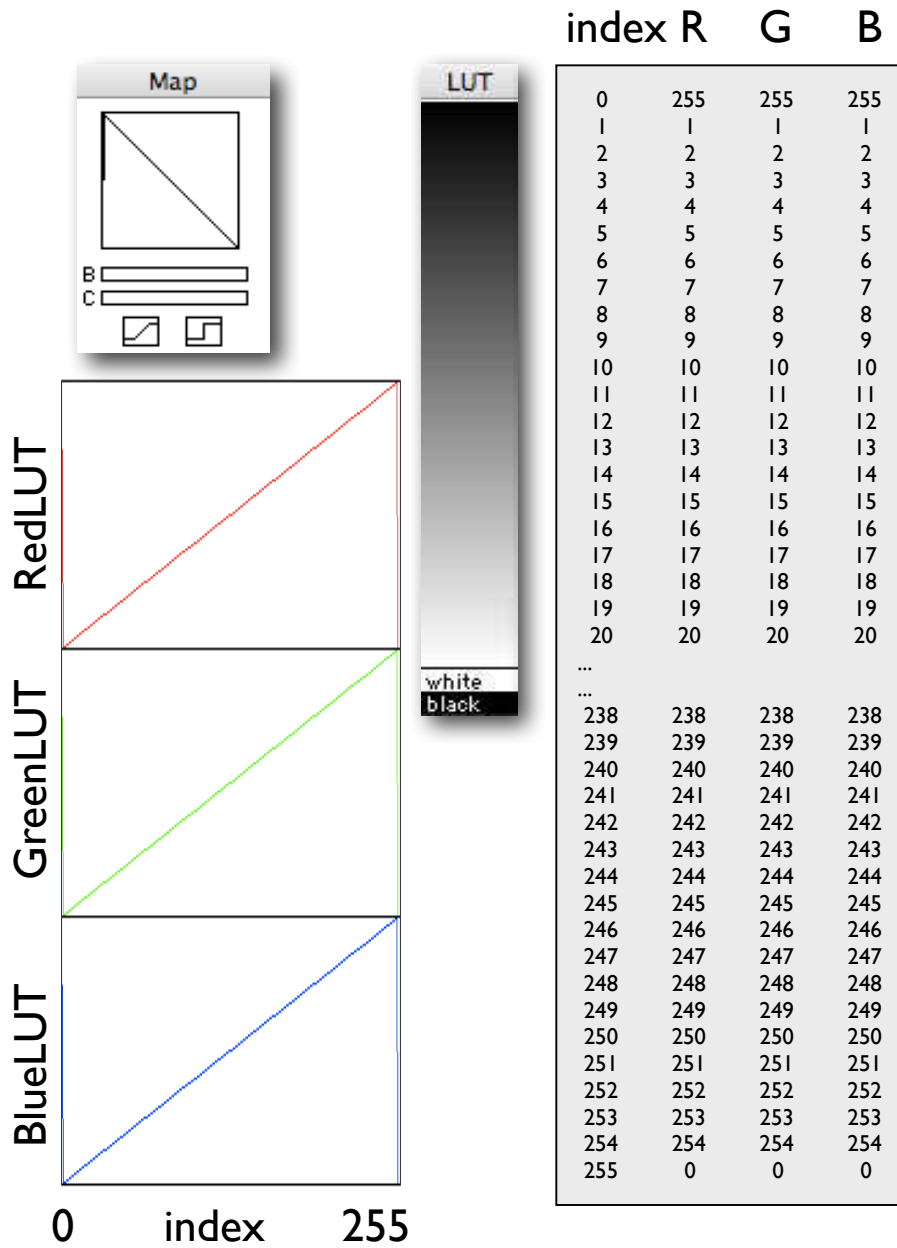
```
macro '-';

macro 'Invert LUT [I]';
var
  i:integer;
begin
  for i:=0 to 255 do begin
    RedLUT[i]:=255-RedLut[i];
    GreenLUT[i]:=255-GreenLut[i];
    BlueLUT[i]:=255-BlueLut[i];
  end;
  UpdateLUT;
end;

macro 'Log Transform';
var
  i,v:integer;
  scale:real;
begin
  scale := 255.0 / ln(255.0);
  for i:=1 to 254 DO begin
    v := 255-round(ln(i) * scale);
    RedLUT[i]:=v;
    GreenLUT[i]:=v;
    BlueLUT[i]:=v;
  end;
  UpdateLUT;
end;

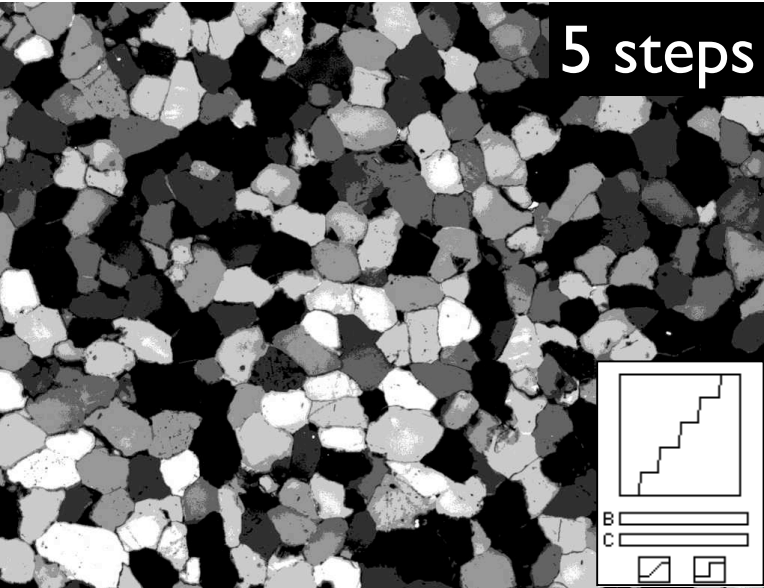
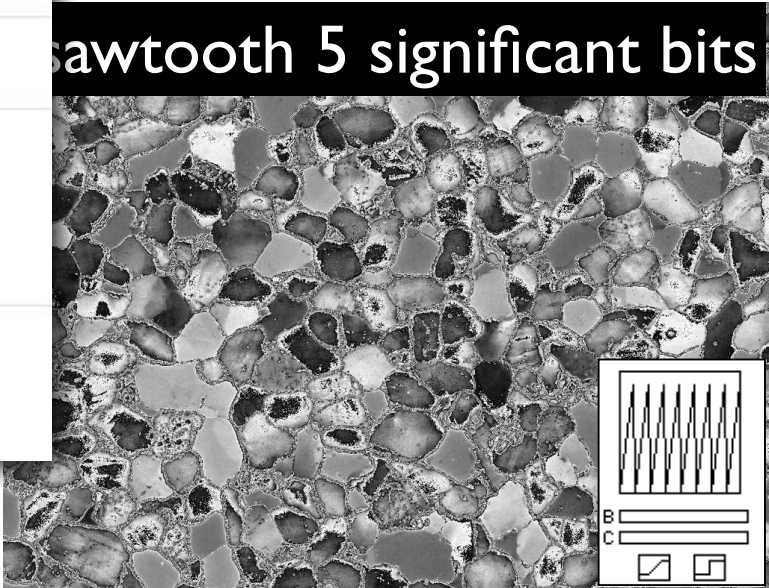
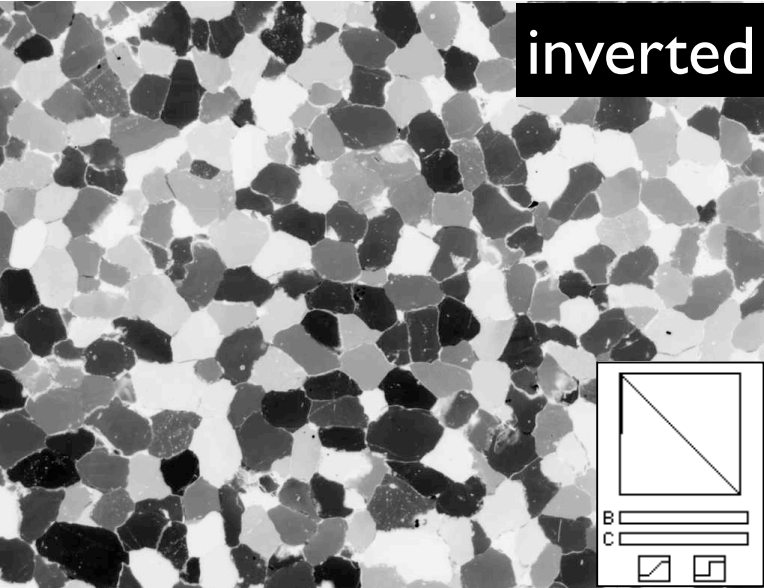
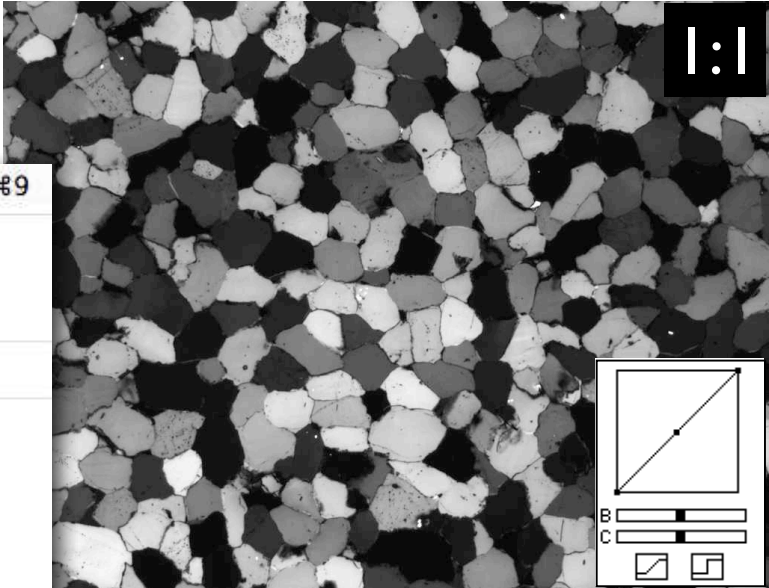
...
..
```

# Plot LUT



# Special LUTs

- Load Macros... ⌘9
- Export LUT [E]
- Import Text LUT
- Plot LUT [P]
- Reset LUT [Z]
- Invert LUT [I] ●
- Log Transform
- Gamma Transform...
- Square Transform
- Parabolic Transform
- Square Root Transform
- Make Steps [T] ●
- Sawtooth [S] ●
- Red LUT [R]
- Green LUT [G]
- Blue LUT [B]
- red-green CIE [1]
- blue-yellow CIE [2]
- Color LUT for 3 phases [3]
- Color LUT for 2 phases [4]
- Color LUT for 6 phases [5]
- Gray LUT for 6 phases [6]





# Color-channels-in-color LUTs

Load Macros... ⌘9

Export LUT [E]  
Import Text LUT  
Plot LUT [P]

Reset LUT [Z]

Invert LUT [I]  
Log Transform  
Gamma Transform...  
Square Transform  
Parabolic Transform  
Square Root Transform

Make Steps [T]  
Sawtooth [S]

Red LUT [R] ●  
Green LUT [G] ●  
Blue LUT [B] ●  
red-green CIE [1]  
blue-yellow CIE [2]

Color LUT for 3 phases [3]  
Color LUT for 2 phases [4]  
Color LUT for 6 phases [5]  
Gray LUT for 6 phases [6]

The preview images show a multi-colored pattern (top left), a grayscale pattern (top middle), a green pattern (top right), a red pattern (bottom left), and a blue pattern (bottom right). The grayscale pattern is labeled 'G', the red pattern is labeled 'R', and the blue pattern is labeled 'B'.



# Color-channels-in-color LUTs

Load Macros... ⌘9

Export LUT [E]  
Import Text LUT  
Plot LUT [P]

Reset LUT [Z]

Invert LUT [I]  
Log Transform  
Gamma Transform...  
Square Transform  
Parabolic Transform  
Square Root Transform

Make Steps [T]  
Sawtooth [S]

Red LUT [R]  
Green LUT [G]  
Blue LUT [B]  
red-green CIE [1]  
blue-yellow CIE [2]

Color LUT for 3 phases [3]  
Color LUT for 2 phases [4]  
Color LUT for 6 phases [5]  
Gray LUT for 6 phases [6]

CIE L

CIE a

CIE b

LUT

LUT

# LUTs for segmentation

The image illustrates the process of applying Look-Up Tables (LUTs) for image segmentation. It is divided into several sections:

- Menu:** A list of operations including:
  - Load Macros... ⌘9
  - Export LUT [E]
  - Import Text LUT
  - Plot LUT [P]
  - Reset LUT [Z]
  - Invert LUT [I]
  - Log Transform
  - Gamma Transform...
  - Square Transform
  - Parabolic Transform
  - Square Root Transform
  - Make Steps [T]
  - Sawtooth [S]
  - Red LUT [R]
  - Green LUT [G]
  - Blue LUT [B]
  - red-green CIE [1]
  - blue-yellow CIE [2]
  - Color LUT for 3 phases [3]
  - Color LUT for 2 phases [4]
  - Color LUT for 6 phases [5]
  - Gray LUT for 6 phases [6]
- Input Image:** A grayscale micrograph of a material with a complex, porous structure.
- Color Segmentation:** The input image is processed with a color LUT, resulting in a multi-colored segmented image. A vertical color bar on the left indicates the mapping of colors to different phases. A histogram and control panels (B, C) are shown to the right.
- Red and Gray Segmentation:** The input image is processed with a red LUT, resulting in a red-and-gray segmented image. A vertical grayscale bar on the right indicates the mapping. A histogram and control panels (B, C) are shown below.
- Binary Segmentation:** The input image is processed with a binary LUT, resulting in a black-and-white segmented image. A vertical grayscale bar on the left indicates the mapping. A histogram and control panels (B, C) are shown to the right.



# Übung 4 - Look Up Tables

Die Wirkungsweise von LUTs erkennen:

- Öffnen Sie ein Bild
- Öffnen Sie das Macro Lazy LUT und laden Sie die das Macro aus dem Fenster

Wenden Sie verschiedene Marcos an und vergleichen Sie die Wirkung mit dem Quelltext

- Schreiben Sie ein Macro, welches Pixel mit Grauwerten zwischen 100 und 155 invertiert, die übrigen Werte aber unverändert lässt.
- Schreiben Sie ein Macro, welches Pixel mit Grauwerten zwischen 100 und 155 auf BLAU setzt, die übrigen Werte aber unverändert lässt.

arithmetic

image math

logical operations

# Arithmetic - ein Bild

The image displays a software interface for image processing. The 'Process' menu is open, showing options like Smooth, Sharpen, Shadow..., Find Edges, Rank Filters..., Dither, Convolve..., Plugin Filters, Binary, Arithmetic, Image Math..., FFT, Subtract Background, Apply LUT, Enhance Contrast, Equalize, Fix Colors, Differential, Curvature, Unsharp Mask, and Hough Transform... The 'Subtract...' option is highlighted. Below the menu, three images are shown: the original image, the result of subtracting 50, and the result of multiplying by 1.5. Histograms are shown below each image.

original

-50

x 1.5



# Image Math - zwei Bilder

Image SXM: Image Math: subtract image1 - image2

70	65	53
65	50	55
53	41	45

10	11	12
13	14	15
16	17	18

60	54	41
52	36	40
37	24	27

$$\boxed{50} - \boxed{14} = \boxed{36}$$

image1

- image2

= image result



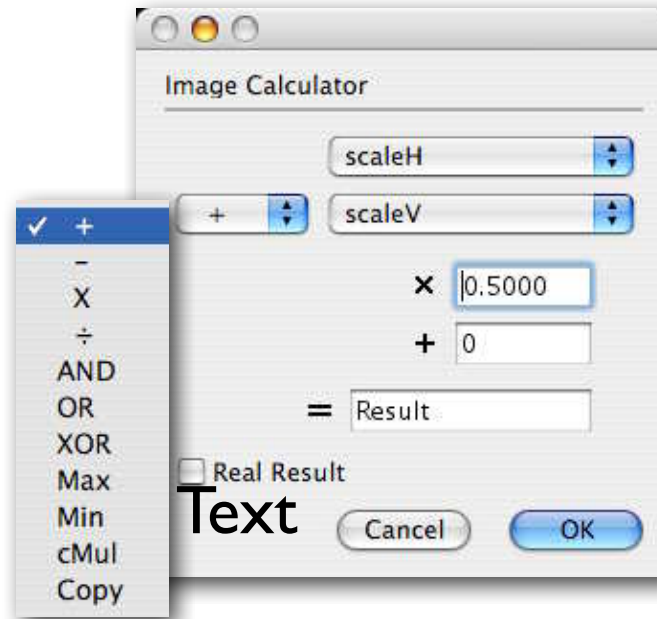
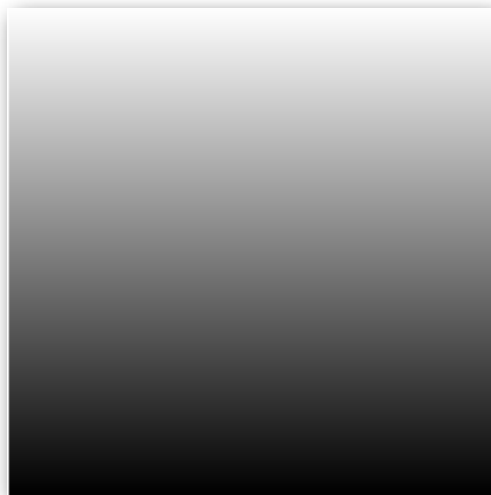
# Image math...

uses 2 images

image 1: scaleH

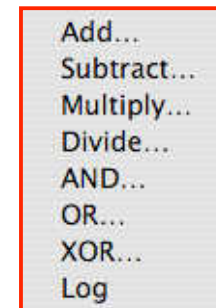
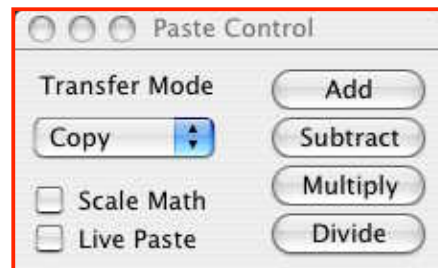


image 2: scaleV



≠ Paste Control...

≠ Arithmetic... - uses 1 image



# Process: Image math

# scaling !

image 1: scaleH



add:  $1+2$



multiply:  $1 \cdot 2$

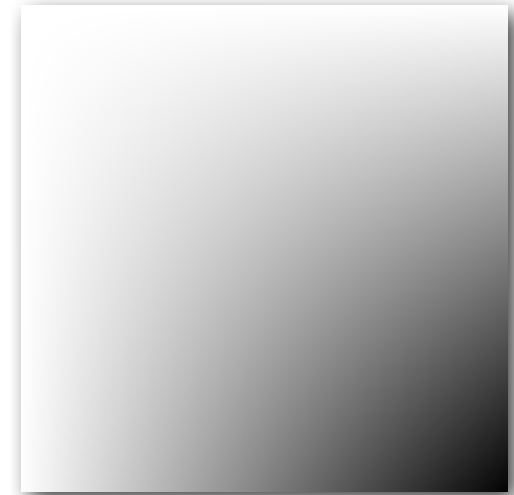
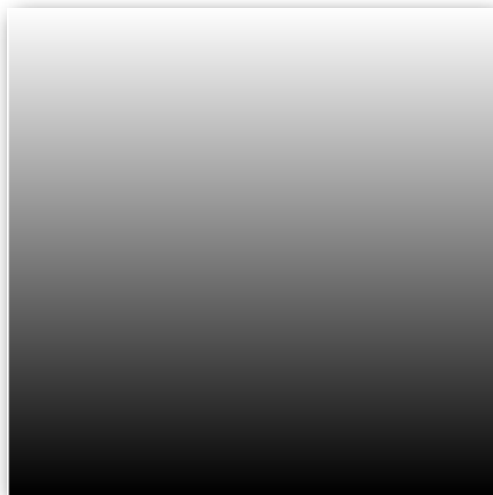


image 2: scaleV



subtract:  $1-2$



divide:  $1/2$





# Binary Operations

image 1

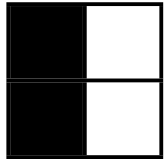
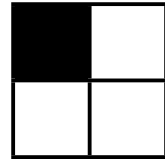
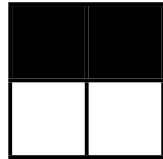


image 2



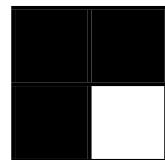
AND

image 1

	1	0
1	1	0
0	0	0

image 2

$(I \cap 2)$

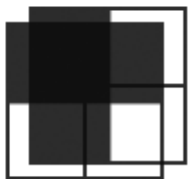


OR

	1	0
1	1	1
0	1	0

$(I \cup 2)$

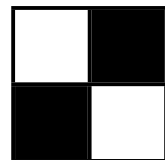
image addition



$1 + 2$



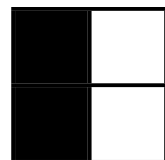
$1 + 1$



XOR

	1	0
1	0	1
0	1	0

$(I \oplus 2)$



COPY

	1	0
1	1	0
0	1	0

# Copy - zwei Bilder

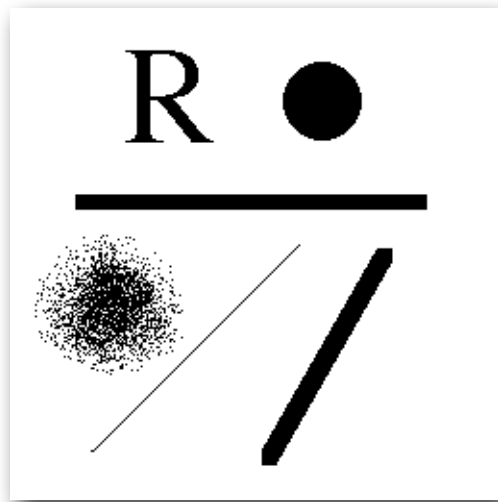
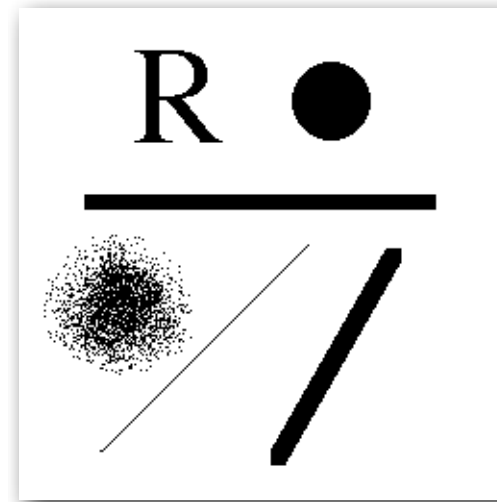


image 1



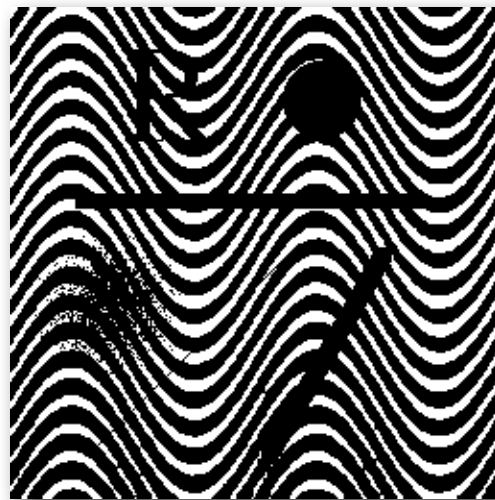
image 2



COPY



AND



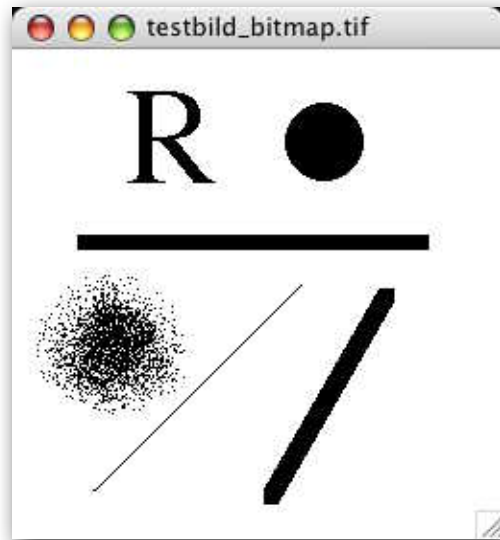
OR



XOR

# Copy - ein Bild

## Rasterverknüpfungen



move image 2:  
 $\Delta x = +2$   $\Delta y = -2$

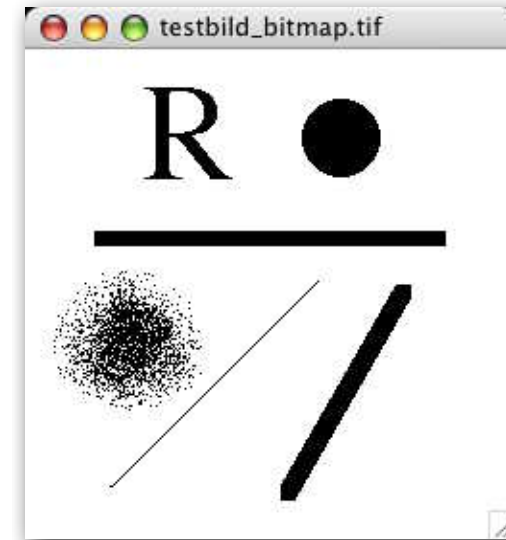
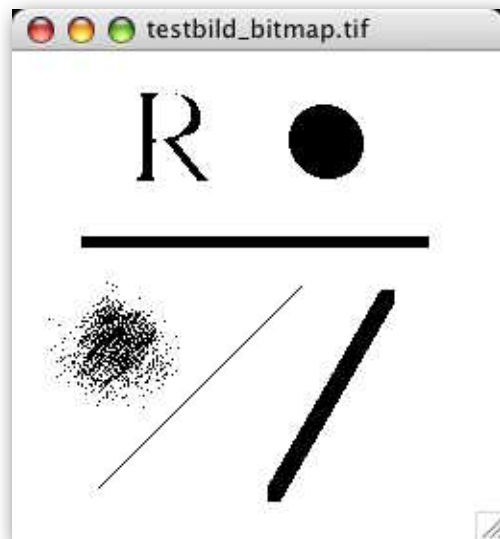
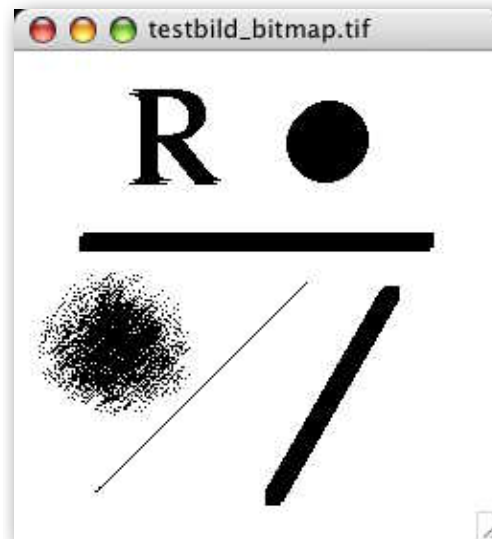


image 1 + image 2

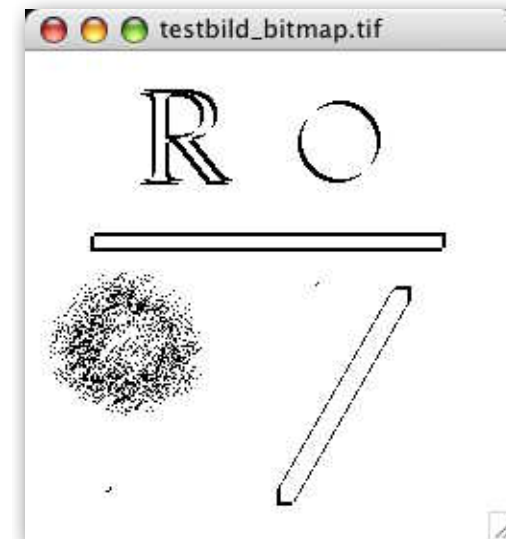
COPY



AND



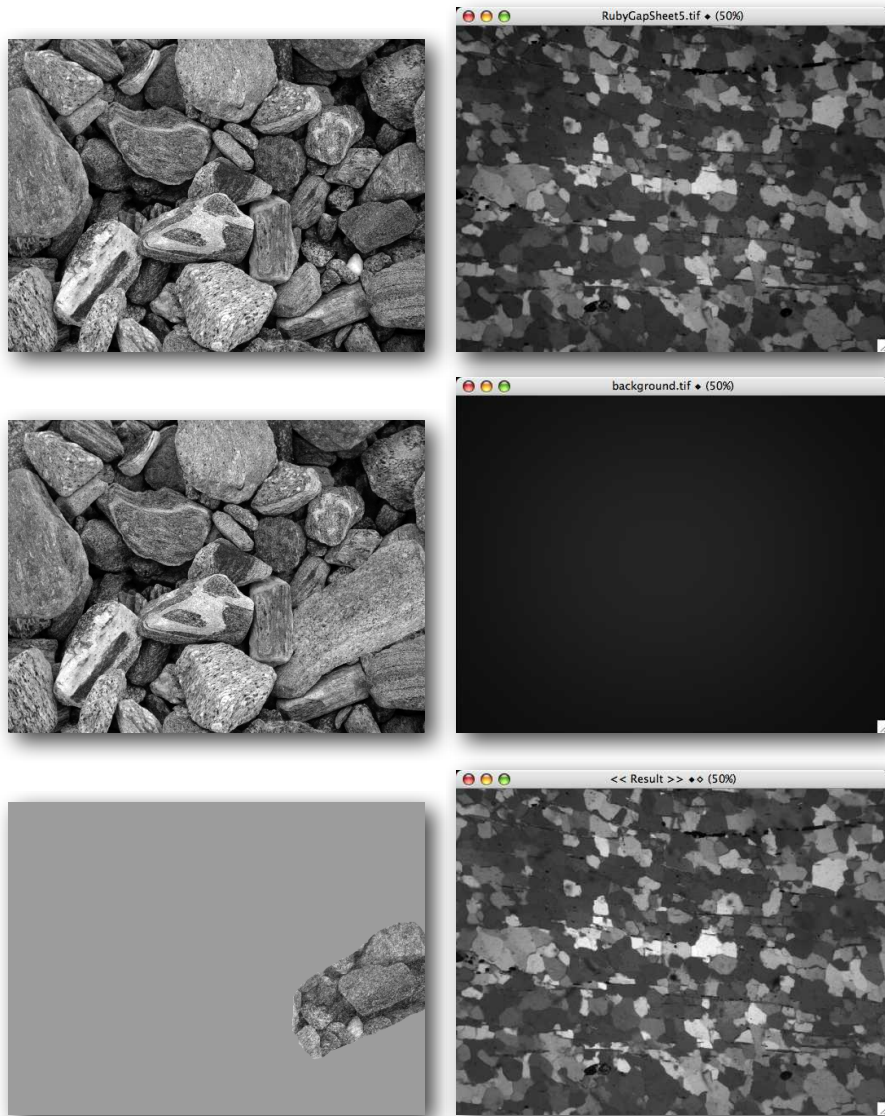
OR



XOR



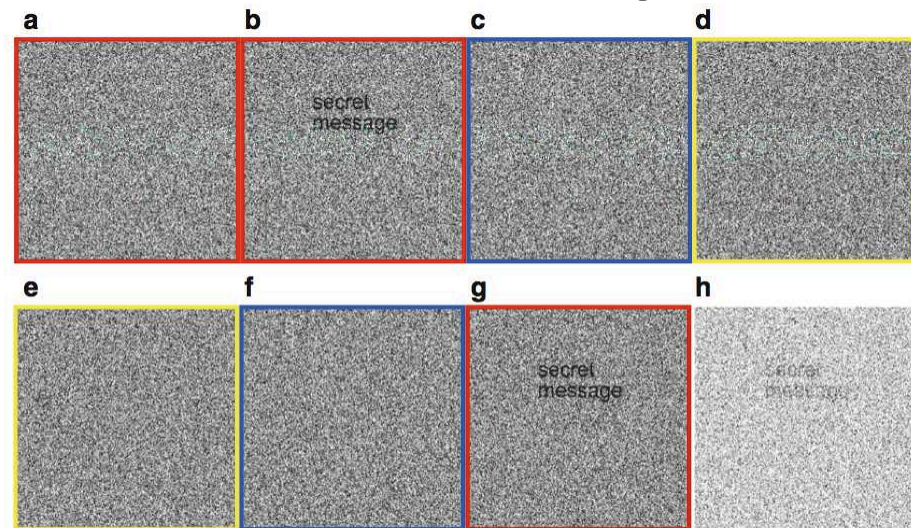
# Differences



1. track movements
2. subtract background
3. monitor processing

....

4. discover secret messages



**Fig. 4.2** Combining images: hiding information in random noise. Coding process: (a) image 1 of random noise; (b) text written on image 1; (c) image 2 of random noise ( $\neq$  image 1); (d) XOR addition of (b) and (c), result = random noise. Decoding process: (e) same as (d) = secret message; (f) same as (c) = key; (g) XOR addition of (e) and (f); (h) subtraction: (e)-(f)

# Übung 5 - Bildunterschiede

Unterschiede zwischen Bildern erkennen bzw. benützen

■ Öffnen Sie die Bilder aloha-pierBLUE.tif und aloha-pierBLUE2.tif. Inwiefern unterscheiden sich die beiden Bilder?

Wie stellen Sie Unterschiede zwischen Bildern fest?

■ Öffnen Sie das Bild Noise bw. Stellen Sie ein zweites Bild gleicher Grösse her und schreiben Sie einen kurzen Text darauf (wenige Worte, grosse Buchstaben benützen). Benützen Sie das Bildpaar um den Text zu verschlüsseln.

Wie gehen Sie vor ?

# DBA 2014


## session 3

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
→ URZ - Universitätsrechenzentrum  
→ VIA - Vorkursangebot  
→ PERSSEARCH - Personensuche

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Rock Information Projects & Software Workshops Textbook DDM Macros Image Macros Image Analysis

LEHRVERANSTALTUNGEN



...l'œil n'est pas "L'appel des cimes" de René Magritte...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehölle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageDM bzw. ImageJ kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageDM software (Mac/OSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Exportation (2-D -> 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software Image DM, bzw. ImageJ (off public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungszahlung möglich)
- Harterter, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET** earth.unibas.ch  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

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→ TROMSØ GEOLOGY HOMEPAGE (Norwegian)  
→ TROMSØ UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>



<http://imagej.nih.gov/ij/>

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## ImageJ News

### Version 1.49h 19 September 2014 (upgrade)

- [1.49h 19 September 2014](#)
  - Selections in the ROI Manager and in overlays can be dragged by their labels. To show labels in the ROI Manager, click on the "Labels" checkbox. To show labels in an overlay, enable "Show labels" in the *Image>Overlay>Labels* dialog.
  - Thanks to Jeremy Adler, added "Type" and "Add to overlay" options to *Edit>Options>Point Tool* dialog. Note that the "Add to overlay" option is not available if the multi-point tool is active.
  - Thanks to Ilan Tal, single macro tools in the macros/toolsets folder added to the toolbar using the toolbar's ">>" menu are restored to the toolbar when ImageJ restarts, as long as the file name matches the tool name and there is a free toolbar slot.
  - Thanks to Philippe Carl and Jerome Mutterer, added the `Roi.contains(x,y)` macro function.
  - Thanks to Thomas Siegmund, the `RoiManager's getRoisAsArray()` method is now synchronized.
  - Thanks to Pedro Pepe, fixed a bug that caused the "Sum Method" of *Image>Stacks>Z Project* to not work correctly with signed 16-bit stacks.
  - Fixed a bug that caused the `makePoint(x,y)` macro function to not work correctly with non-integer coordinates.
  - Thanks to Norbert Vischer, fixed a bug that sometimes caused `setThreshold()` to fail in batch mode macros.
  - Thanks to Pedro Ramos Cabrer and Michael Schmid, fixed a 1.46 regression that caused 4 or 5 parameter custom curve fits to be much slower.
  - Fixed a regression than sometimes caused the *Image>Duplicate* command to not be correctly recorded.
- [1.49g 25 August 2014](#)
  - Thanks to Jon Harman, pinch to zoom works on Windows 8 tablets and touch screen laptops.
  - Thanks to Sean Smith, mouse wheel scrolling is faster on Windows.
  - Improved script-mode recording of commands in the *Edit>Selection* submenu.
  - Thanks to Neil Fazel, fixed a bug that caused the *Analyze>Tools>Save XY Coordinates* command to not work with NaN backgrounds.

<http://imagej.nih.gov/ij/docs/guide/146.html>

# <http://imagej.nih.gov/ij/developer/macro/functions.html>

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## Built-in Macro Functions

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[ [N](#) ] [ [O](#) ] [ [P](#) ] [ [Q](#) ] [ [R](#) ] [ [S](#) ] [ [T](#) ] [ [U](#) ] [ [V](#) ] [ [W](#) ] [ [X](#) ] [ [Y](#) ] [ [Z](#) ]

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### **abs(n)**

Returns the absolute value of *n*.

### **acos(n)**

Returns the inverse cosine (in radians) of *n*.

### **Array Functions**

These functions operate on arrays. Refer to the [ArrayFunctions](#) macro for examples.

**Array.concat(array1,array2)** - Returns a new array created by joining two or more arrays or values ([examples](#)). Requires 1.46c.

**Array.copy(array)** - Returns a copy of *array*.

**Array.fill(array, value)** - Assigns the specified numeric value to each element of *array*.

**Array.findMaxima(array, tolerance)** - Returns an array holding the peak positions (sorted with descending strength). Tolerance is the minimum amplitude difference needed to separate two peaks. There is an optional 'excludeOnEdges' argument that defaults to 'true'. [Examples](#). Requires 1.48c.

**Array.findMinima(array, tolerance)** - Returns an array holding the minima positions. Requires 1.48c.

**Array.fourier(array, windowType)** - Calculates and returns the Fourier amplitudes of *array*. *WindowType* can be "none", "Hamming", "Hann", or "flat-top", or may be omitted (meaning "none"). See the [TestArrayFourier](#) macro for an example and more documentation. Requires 1.49i.

**Array.getStatistics(array, min, max, mean, stdDev)** - Returns the *min*, *max*, *mean*, and *stdDev* of *array*, which must contain all numbers.

**Array.print(array)** - Prints the array on a single line. Requires 1.46c.

**Array.rankPositions(array)** - Returns, as an array, the rank positions of *array*, which must contain all numbers or all strings ([example](#)).

**Array.resample(array,len)** - Returns an array which is linearly resampled to a different length. Requires 1.47j.

**Array.reverse(array)** - Reverses (inverts) the order of the elements in *array*. Requires 1.46c.

**Array.show(array)** - Displays the contents of *array* in a window. Requires 1.48d.

**Array.show("title", array1, array2, ...)** - Displays one or more arrays in











# <http://imagej.nih.gov/ij/macros/>

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# ImageJ

Image Processing and Analysis in Java

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 <a href="#">ArrayConcatExamples.txt</a>	13-Dec-2011 07:29
 <a href="#">ArrayFunctions.txt</a>	29-Jul-2010 14:18
 <a href="#">ArraySliceExamples.txt</a>	06-Dec-2011 20:07
 <a href="#">ArraySortingDemo.txt</a>	12-Nov-2010 09:09
 <a href="#">Arrows.txt</a>	20-Apr-2014 23:45
 <a href="#">AutoThresholdingDemo.txt</a>	29-Jul-2010 14:18
 <a href="#">BatchMeasureWithRedirectedErrors.txt</a>	07-Sep-2013 21:34

## Plugins

### Contents

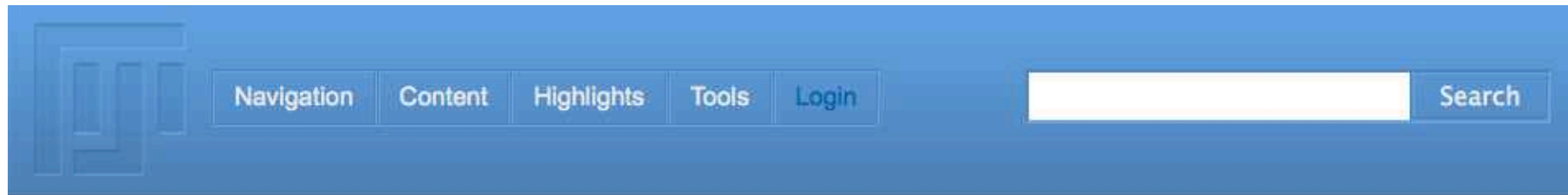
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- [Hamamatsu Orca 12-bit Camera](#)
- [Shading Corrector](#)
- [QuickTime Capture \(Capture images using TWAIN\)](#)
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- [Twain Scan](#)
- [SensiCam Long Exposure Camera](#)
- [Video Capture Macro Tool \(Video for Windows via VirtualDub\)](#)
- [Capturing plugin \(Captures images on Windows using JMF\)](#)

- [www.qimaging.com](http://www.qimaging.com): QImaging Firewire Cameras
- [ScionFGAkiz](#): Scion full-frame-rate capture
- [FWCamAkiz](#): Mac OS X Firewire Cameras
- [www.pixelsmart.com](http://www.pixelsmart.com): PixelSmart Frame Grabbers
- [www.bruyton.com](http://www.bruyton.com): Andor, Cooke, Hamamatsu, PCO, Princeton Instruments...





## Fiji Is Just ImageJ

[QR for this page](#)

Fiji is an image processing package. It can be described as a distribution of [ImageJ](#) (and [ImageJ2](#)) together with Java, Java3D and a lot of [plugins](#) organized into a [coherent menu structure](#). Fiji compares to ImageJ as Ubuntu compares to Linux.

The main focus of Fiji is to assist research in life sciences.

For [users](#), Fiji is [easy to install](#) and has an automatic update function, bundles a lot of [plugins](#) and offers comprehensive [documentation](#).

For [developers](#), Fiji is an open source project hosted in a [Git version control repository](#), with access to the source code of all internals, libraries and plugins, and eases the [development](#) and [scripting](#) of plugins.

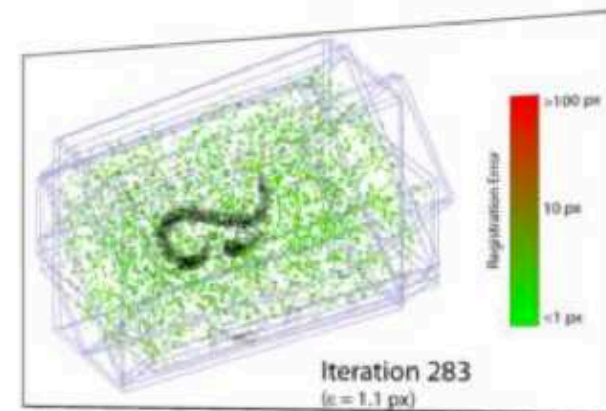
[Download Fiji now](#)



[List of Update sites](#)

[How to cite Fiji?](#)

[Who is citing Fiji?](#)





The [SPIM Registration](#) plugin provides fast, reliable and high-precision registration and fusion of Selective Plane Illumination Microscopy data as well as other 3d multi-angle image acquisitions.

# <http://fiji.sc/Downloads>

## Download

### Fiji continuous release

The latest version of Fiji is automatically and continuously built by the [ImageJ Jenkins server](#).

 <a href="#">All platforms (no JREs)</a>	 <a href="#">Windows (32-bit)</a>	 <a href="#">OS X</a>	 <a href="#">Linux (32-bit)</a>
	<a href="#">Windows (64-bit)</a>		

### Fiji Life-Line version, 2014 June 2

As announced in [this blog post](#), we updated ImageJ2 with some rather dramatic changes under the hood. The packages below reflect Fiji as of June 2nd, 2014 and are offered here just in case the continuous build (or an updated version) above broke a formerly working operation that is desperately needed, like, right now.

 <a href="#">All platforms (no JREs)</a>	 <a href="#">Windows (32-bit)</a>	 <a href="#">OS X</a>	 <a href="#">Linux (32-bit)</a>
	<a href="#">Windows (64-bit)</a>		

### Fiji Life-Line version, 2013 July 15

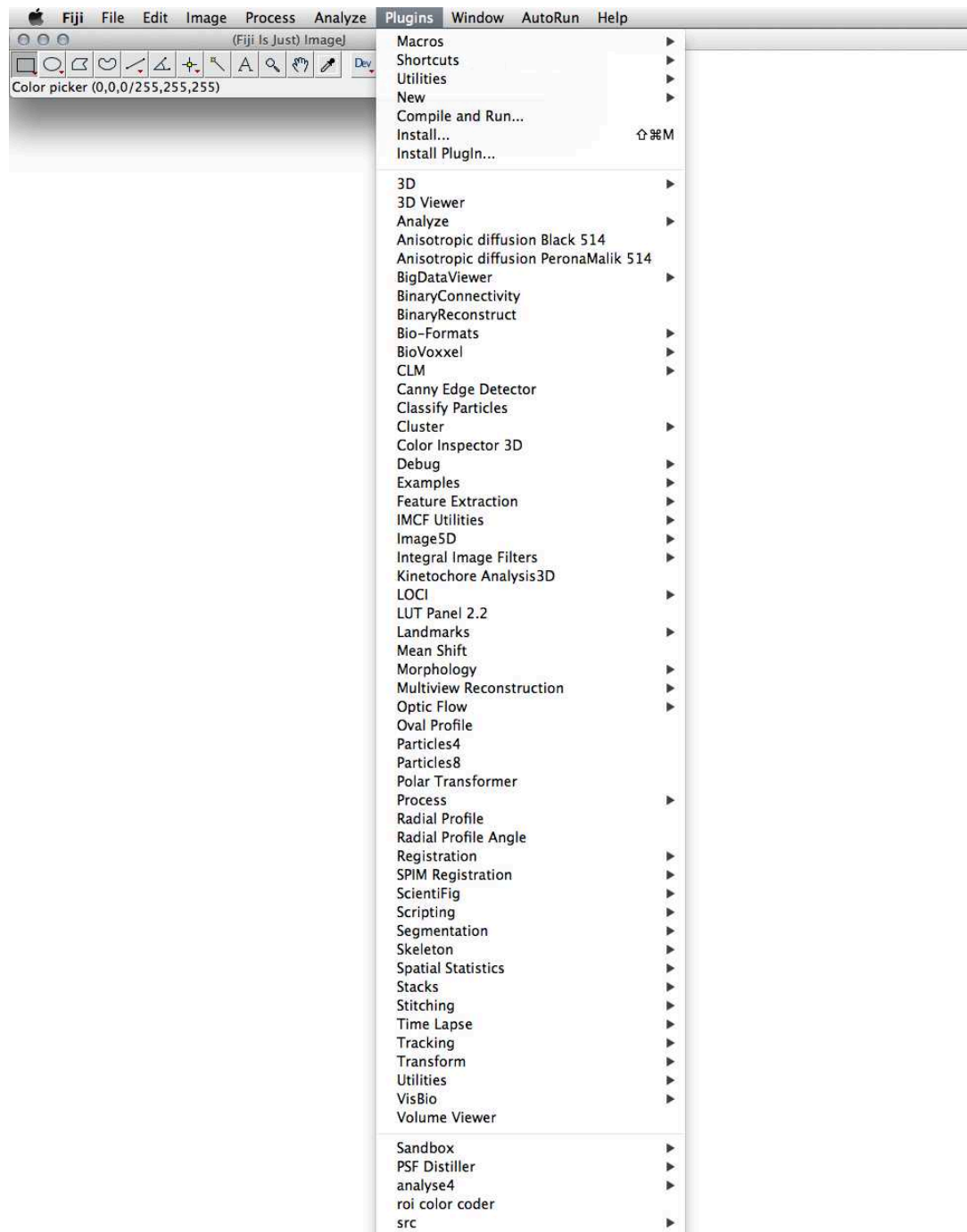
As announced in [this mail](#), we join the legions of construction workers digging up the streets during the second half of July 2013 (i.e. we also use the slow summer month to break things in order to make them better), incorporating extensive changes to reconcile Fiji with ImageJ2. The packages below reflect Fiji as of July 15th, 2013 and are offered here just in case the continuous build (or an updated version) above broke a formerly working operation that is desperately needed, like, right now.

 <a href="#">All platforms (no JREs)</a>	 <a href="#">Windows (32-bit)</a>	 <a href="#">OS X</a>	 <a href="#">Linux (32-bit)</a>
	<a href="#">Windows (64-bit)</a>		

### ImageJ development snapshot

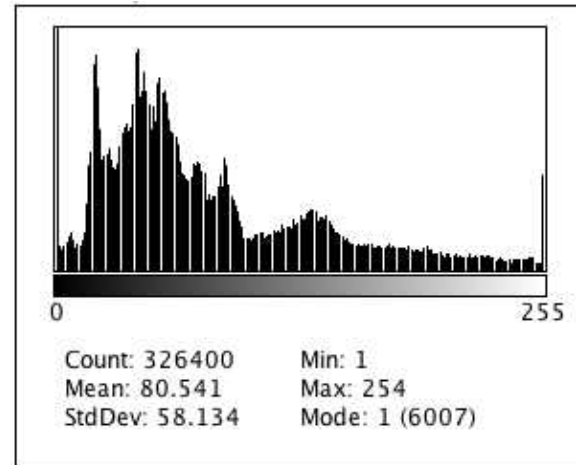
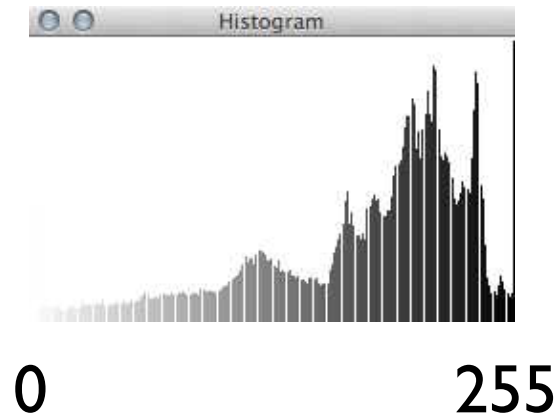
You can download the latest DEVELOPMENT, UNSTABLE application bundle of ImageJ. This build includes the latest changes on the [master branch of the source repository](#). It has not been thoroughly tested and may contain new bugs.

 <a href="#">All platforms (no JREs)</a>
---





# Vergleich: ImageSXM - imagej



imagej

Histogram: Bild, jeweils nur für aktives Fenster

GW Operationen auf der LUT

Unterstützt RGB, 8, 16, 32bit

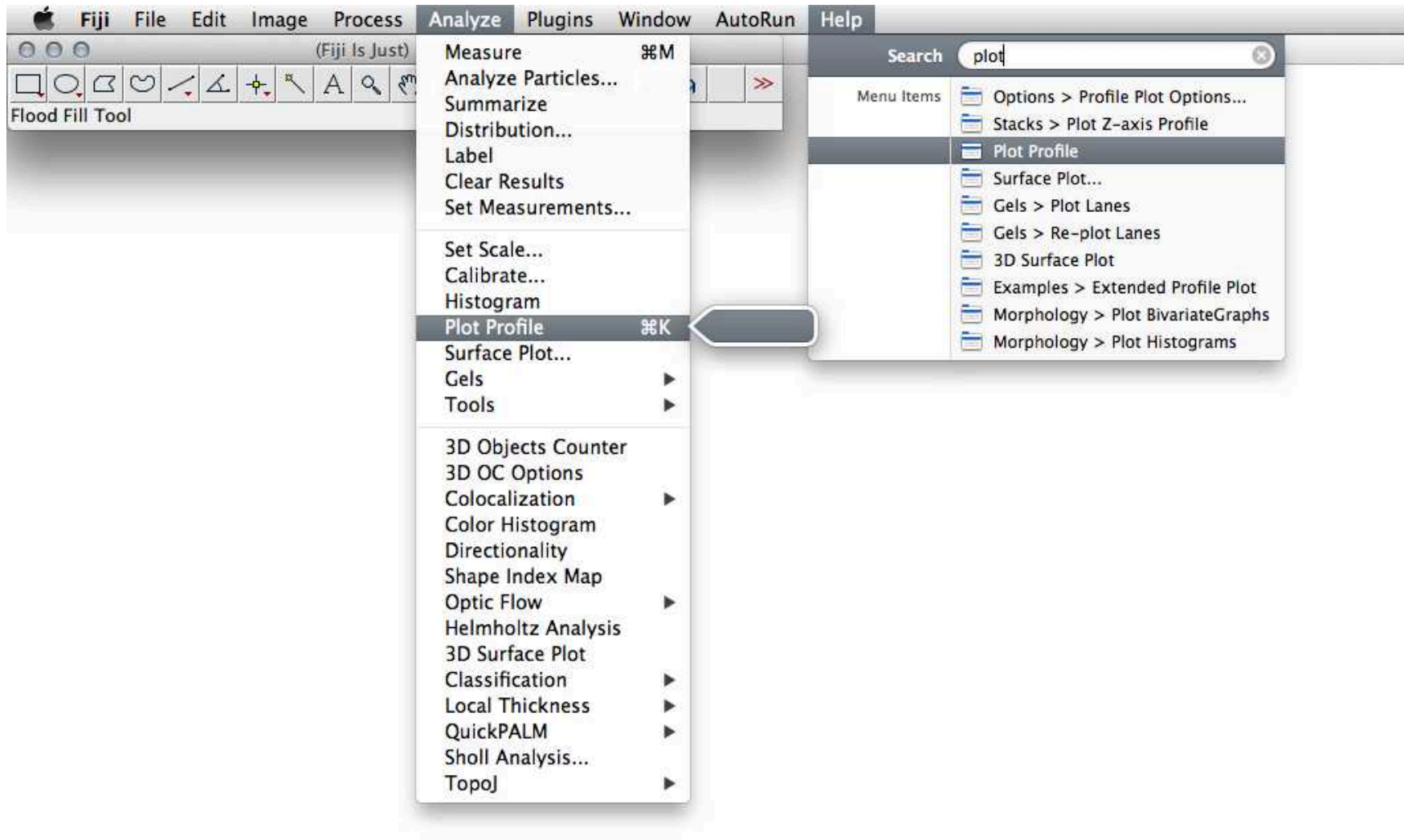
Overlays, ROIs

unterstützt Menu Help (OSX,KDE,Gnome,Windows...)

open source (<http://rsb.info.nih.gov/ij/developer/source/>)

imageSXM macro language  $\neq$  imagej macro language(s)

# Funktionen finden



Skalieren,  
Kalibrieren,  
Bildgrösse ändern



# scale and calibrate $\neq$ re-size

scaling:  $x = \text{scaling factor} \cdot X$

$y = \text{scaling factor} \cdot Y$

scaling factor defines true size of pixel

calibrating:  $gv = \text{calibration} \cdot GV$

calibration defines true value of GV

$X, Y, GV = \text{integer}$

$x, y, gv = \text{real, but still discrete values}$

image size ( $X \cdot Y \cdot \text{depth}$ ) is unchanged

# Übung 6 - Skalieren und Kalibrieren

Die räumlichen Dimensionen und die Grauwerte eichen.

■ Das Bild 1047cropnonscal.tif (im Ordner DEM maps) öffnen.

Skalieren Sie die X,Y Koordinaten und kalibrieren Sie die Grauwerte Z.

Es gibt für zwei Grauwerte eine Höheneichung:

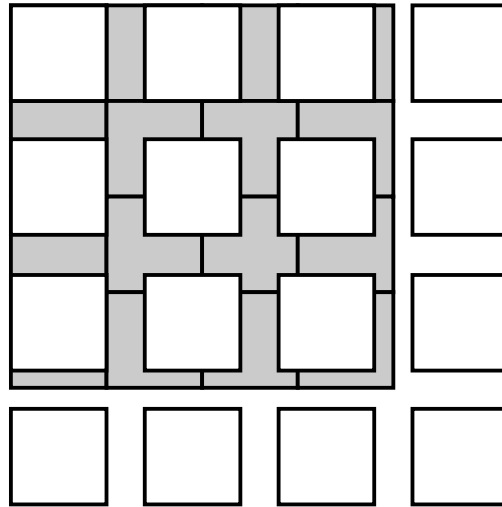
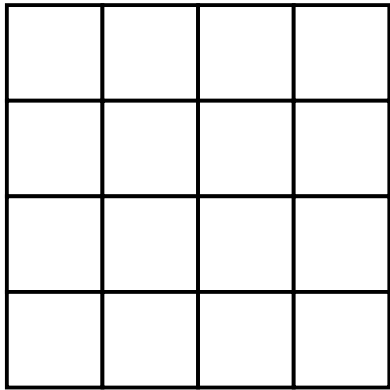
Grauwert in SXM (imagej)	Höhe u.M.
89 (255-89)	339.13 m
72 (255-72)	374.07 m

aber keine Angaben zum Massstab.

Wie gehen Sie vor ?

Tipp: Benutzen sie eine Karte (oder zur Not hier google maps?)

# Re-sizing: Bildgrösse ändern



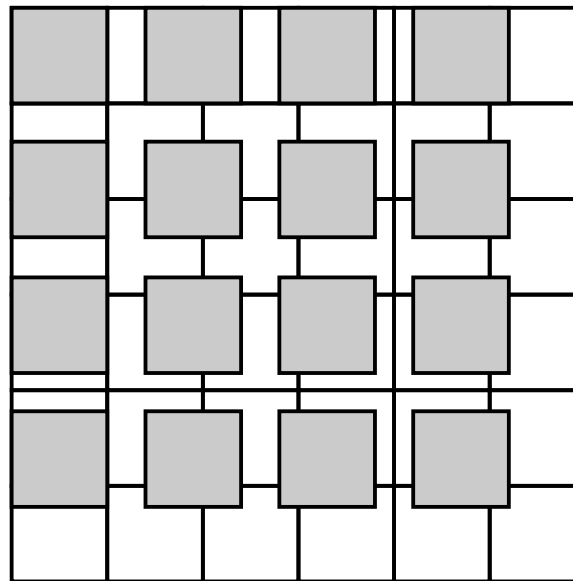
forward transform:

$$x' = A_{ij} x$$

$$x' = \text{new}$$

$$x = \text{old}$$

new in terms of old



$$x = A_{ij}^{-1} x'$$

$$x' = \text{new}$$

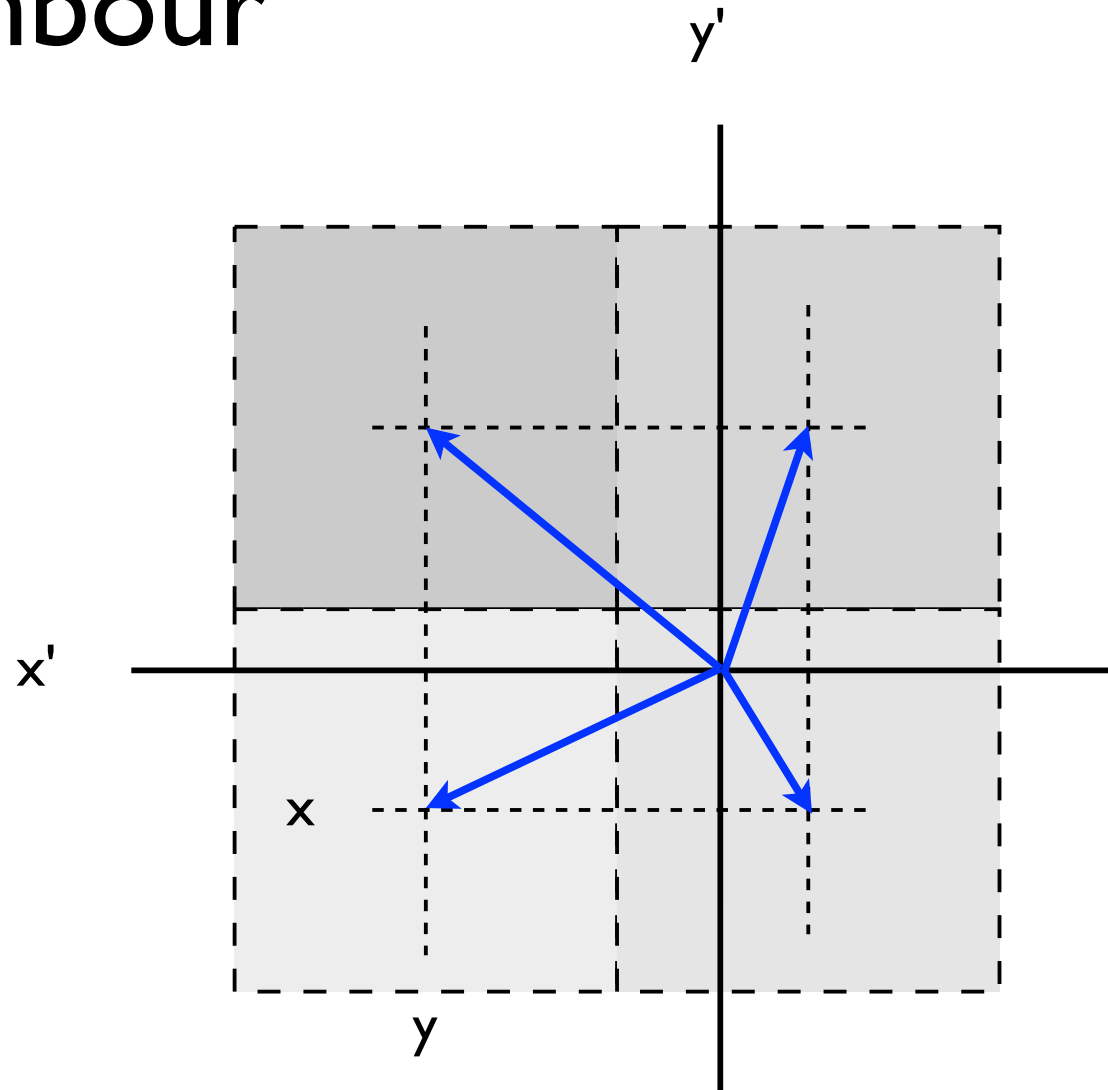
$$x = \text{old}$$

old in terms of new

# Nearest Neighbour

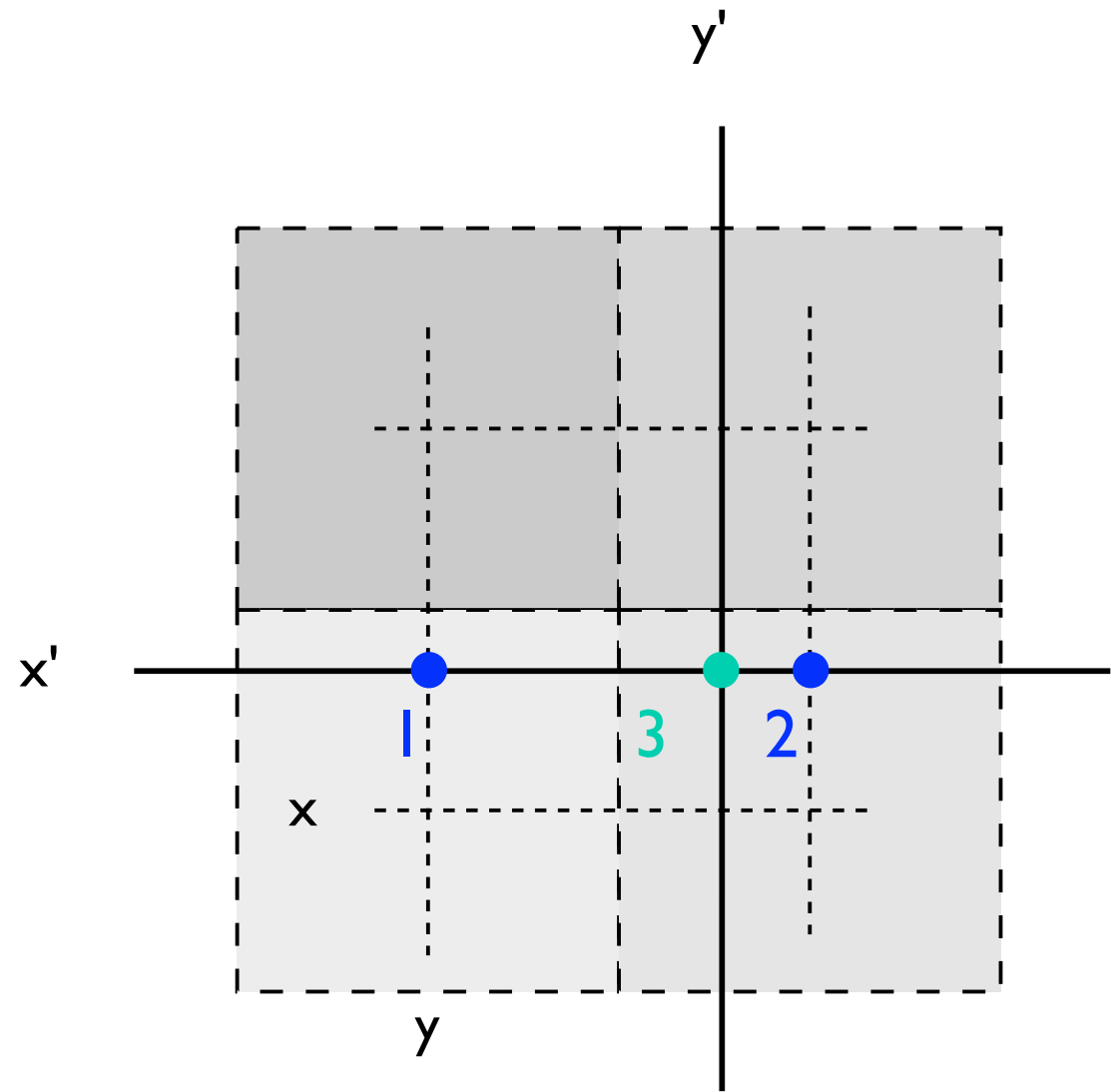
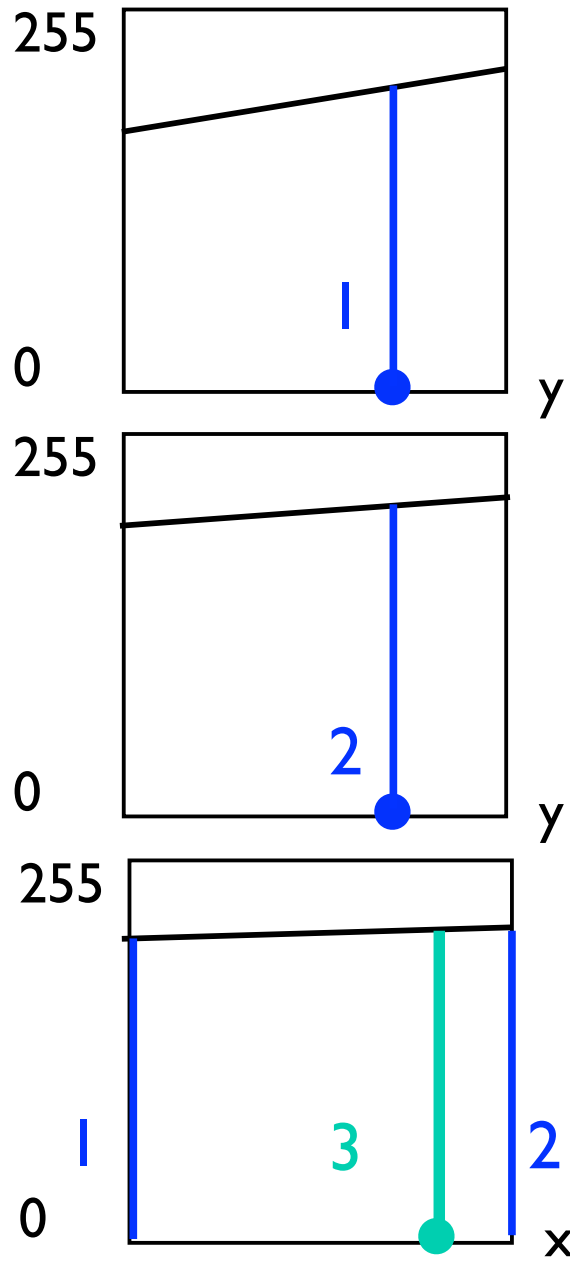
NN

duplicate colour of  
nearest neighbour





# Bilinear interpolation



# 'Das wohltemperierte Klavier'

a''	880.000
g#''	830.609
g''	783.991
f#''	739.989
f''	698.456
e''	659.255
d#''	622.254
d''	587.330
c#''	554.365
c''	523.251
b'	493.883
a#'	466.164
a'	440.000

chromatic scale:

12 halftones / octave

1 octave = 2 · frequency

⇒ frequency ratio between halftones:

$$\sqrt[12]{2} = 1.05946$$

analogously:

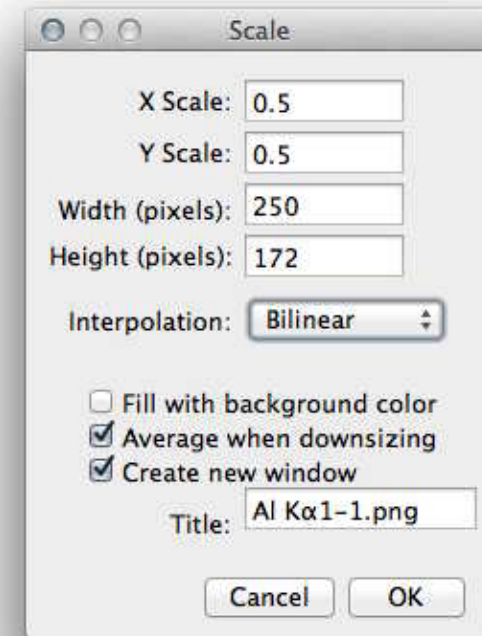
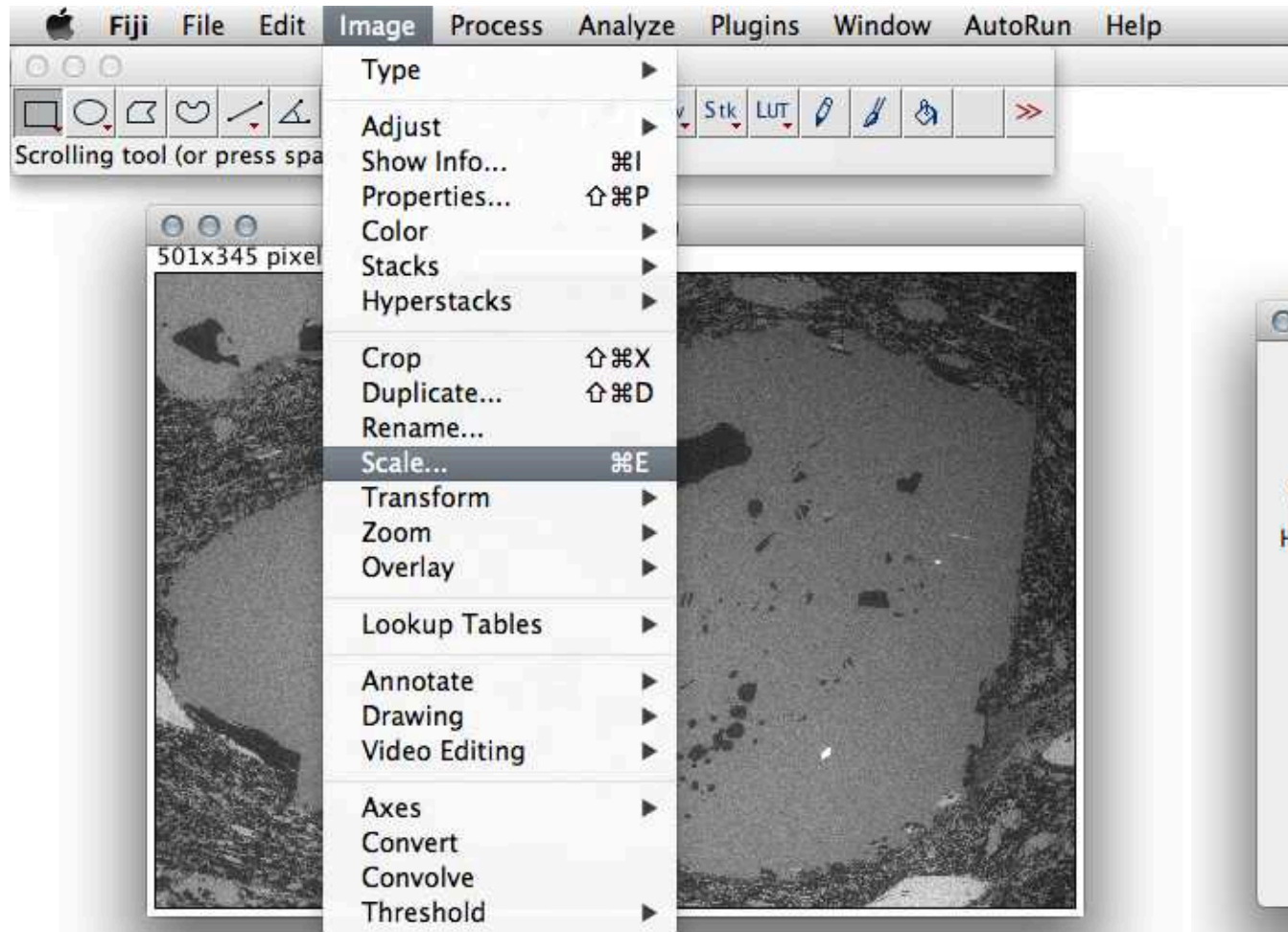
$$\sqrt[s]{M} = m$$

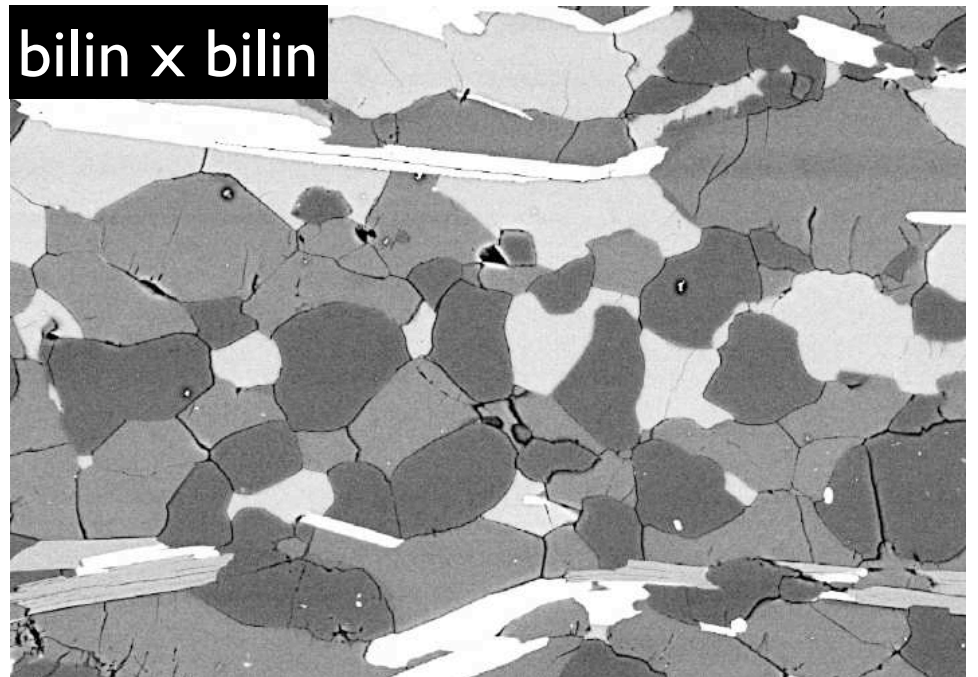
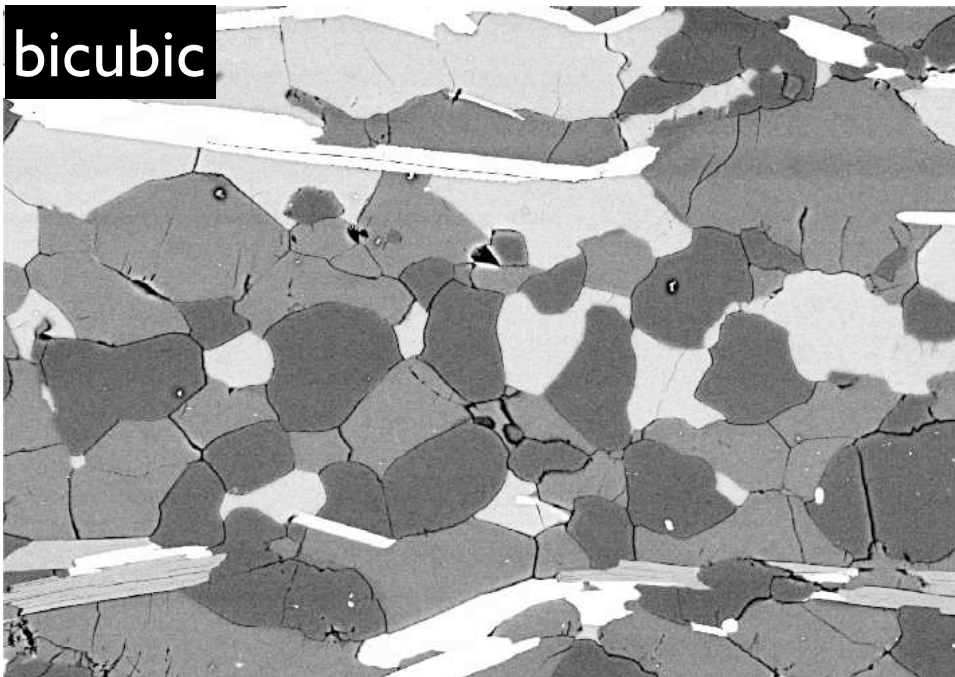
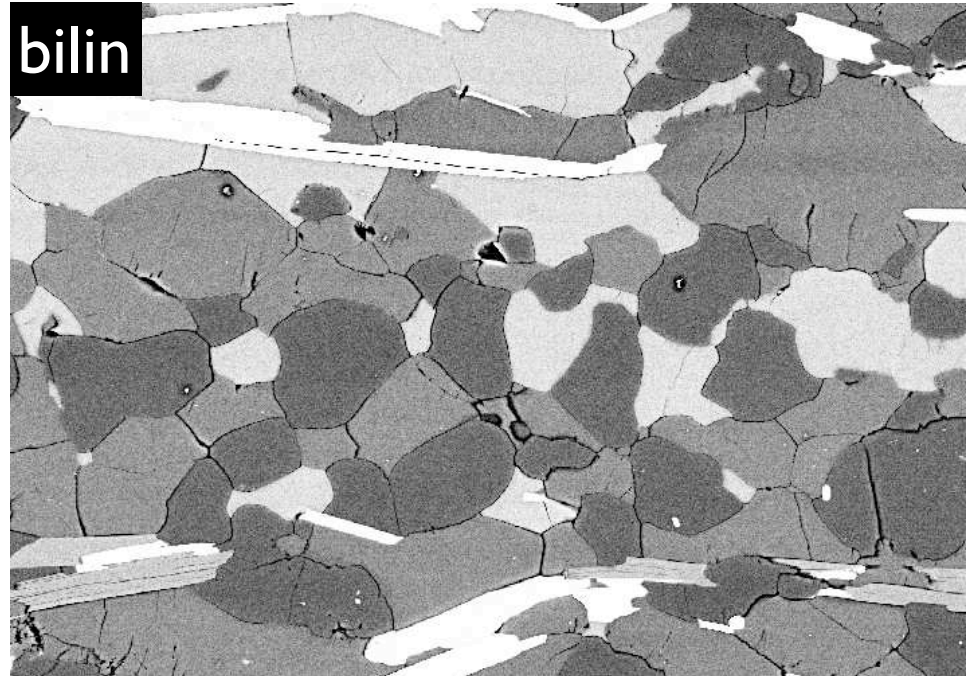
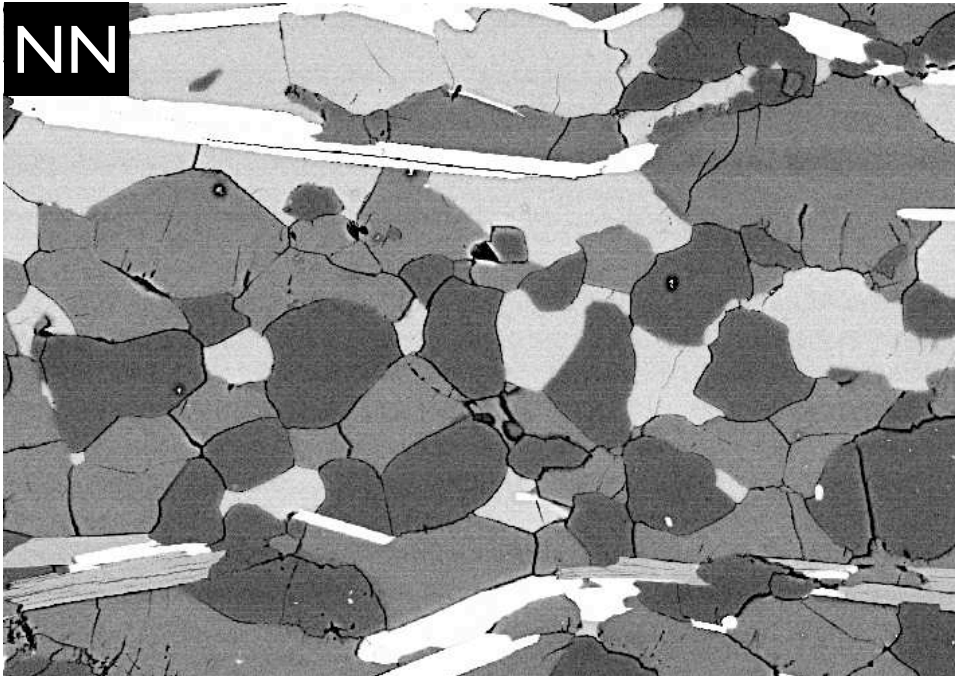
M desired final magnification

s number of steps

m magnification at each step

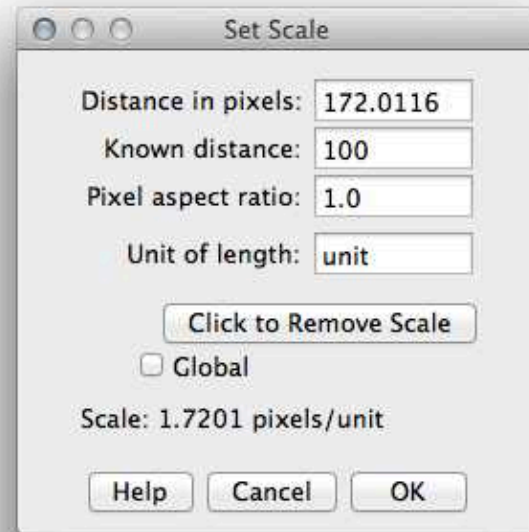
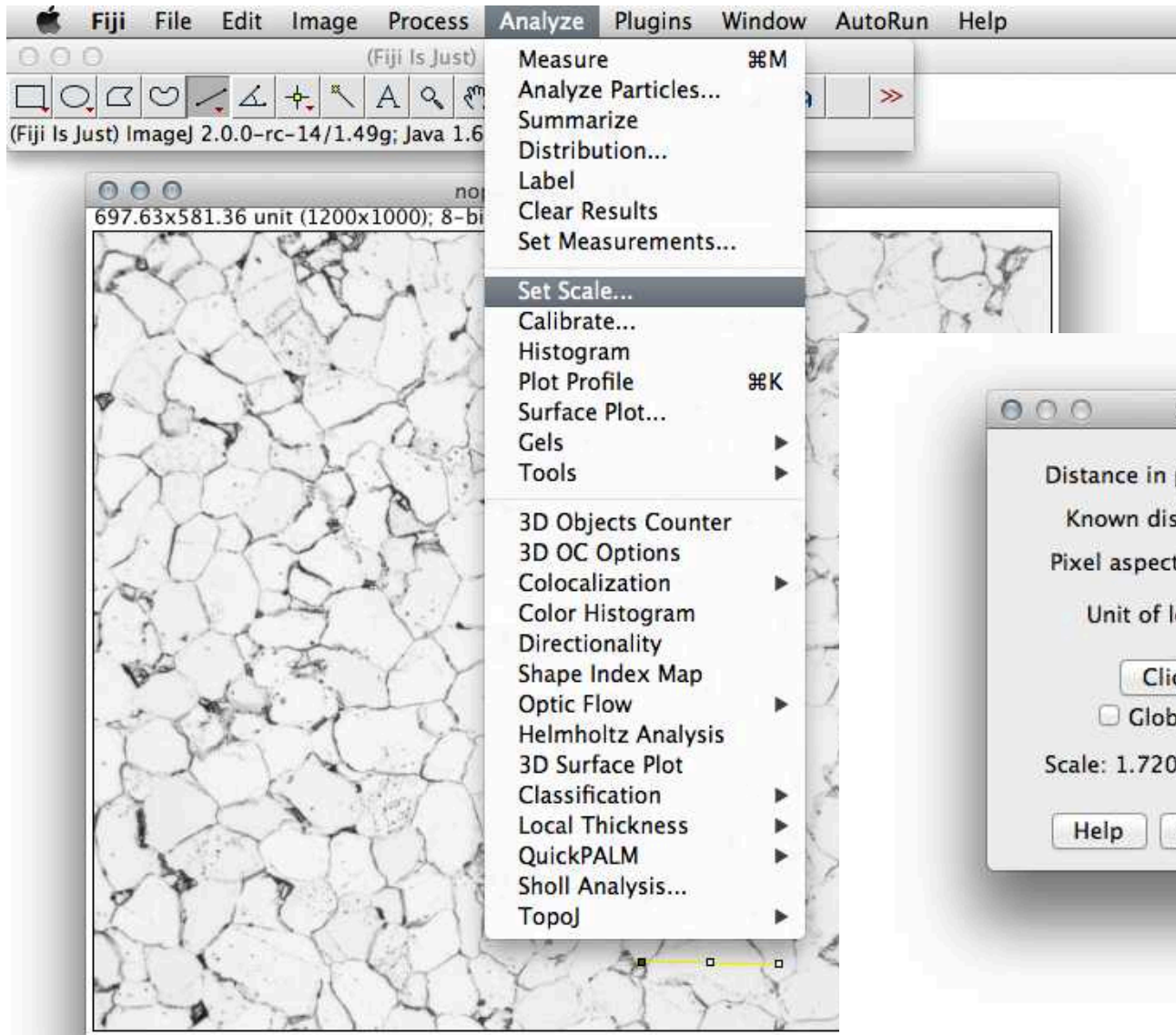
# Bildgrösse ändern: Scale



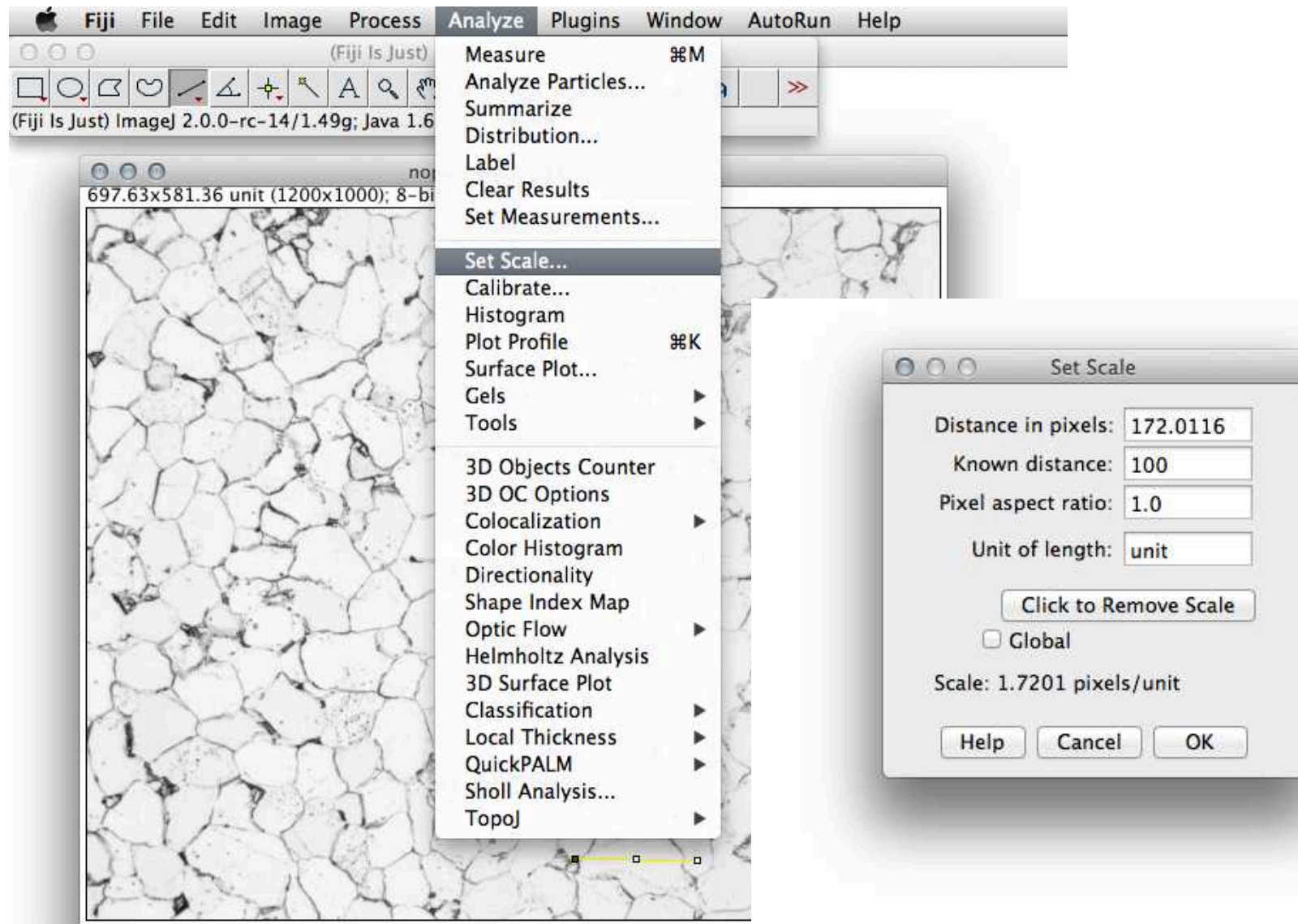




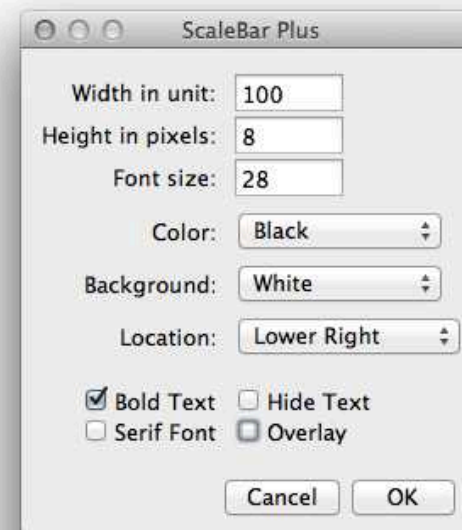
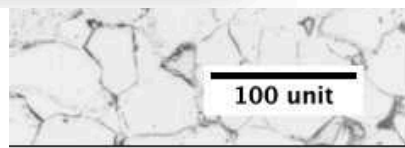
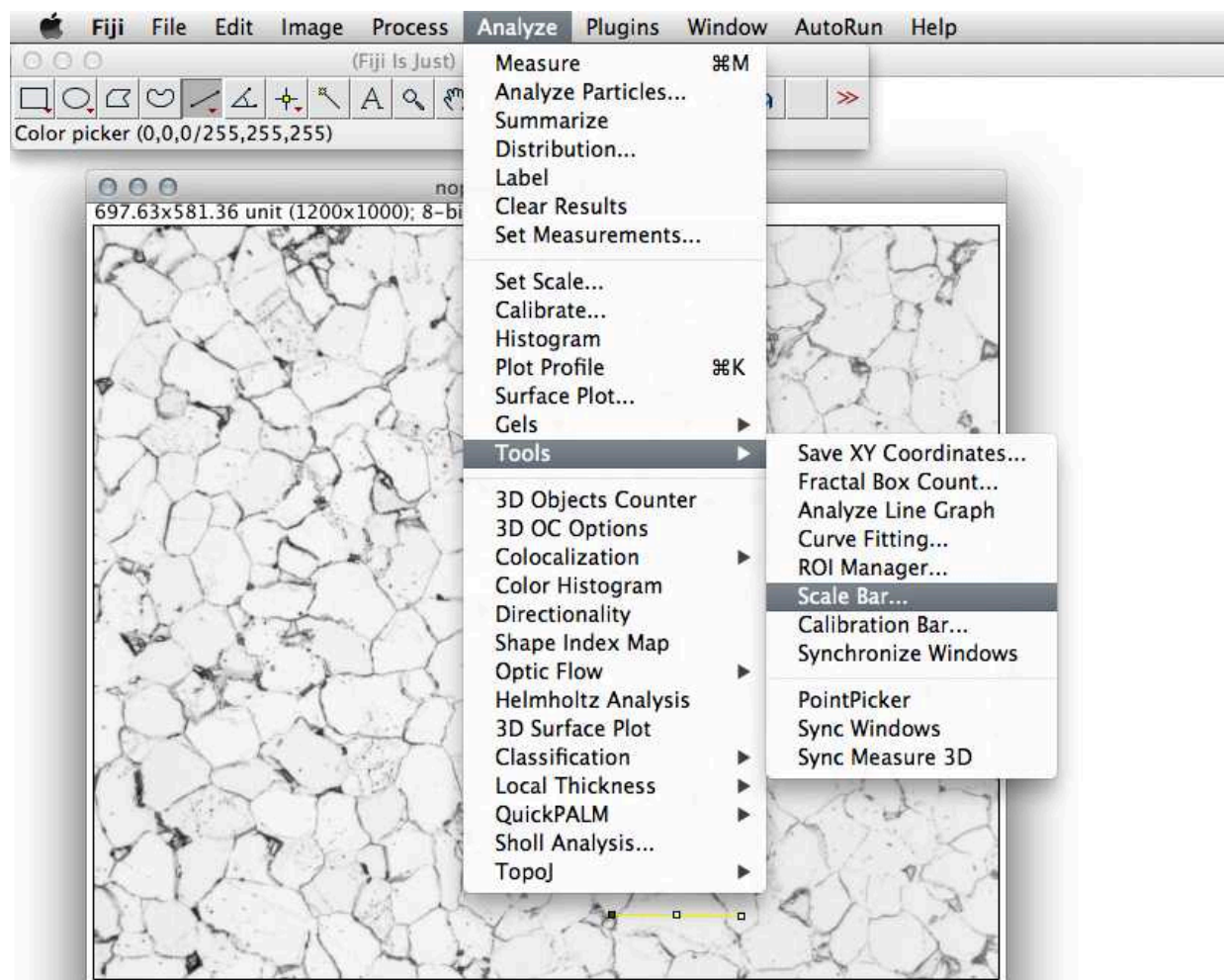
# Skalieren: Set scale



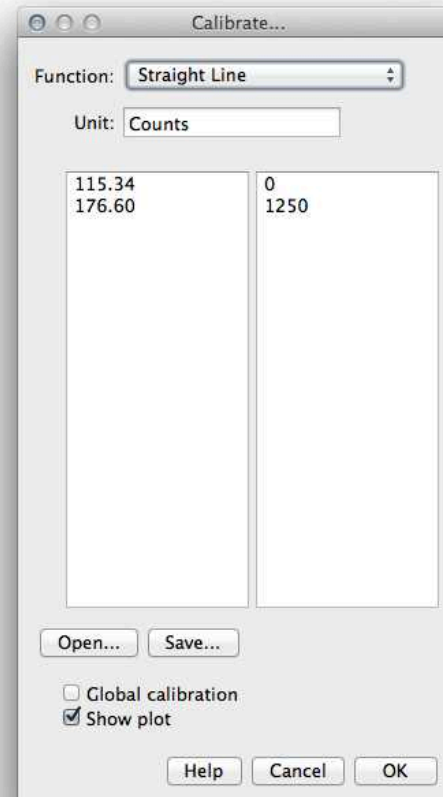
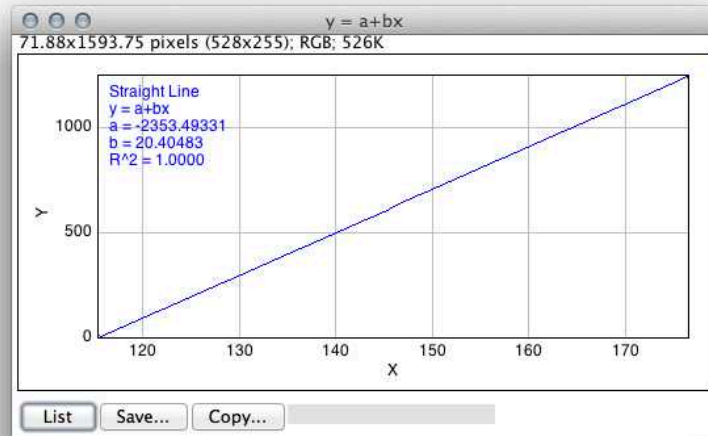
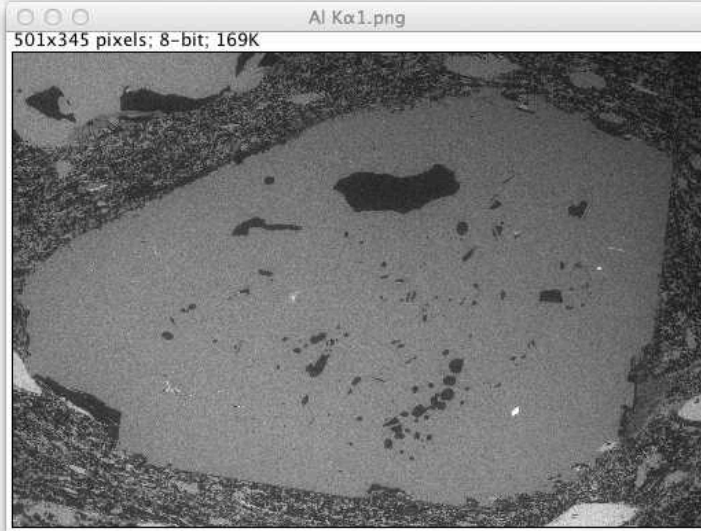
# Skalieren: scale (resize) $\neq$ Set scale



# Scale Bar: x,y-Skala



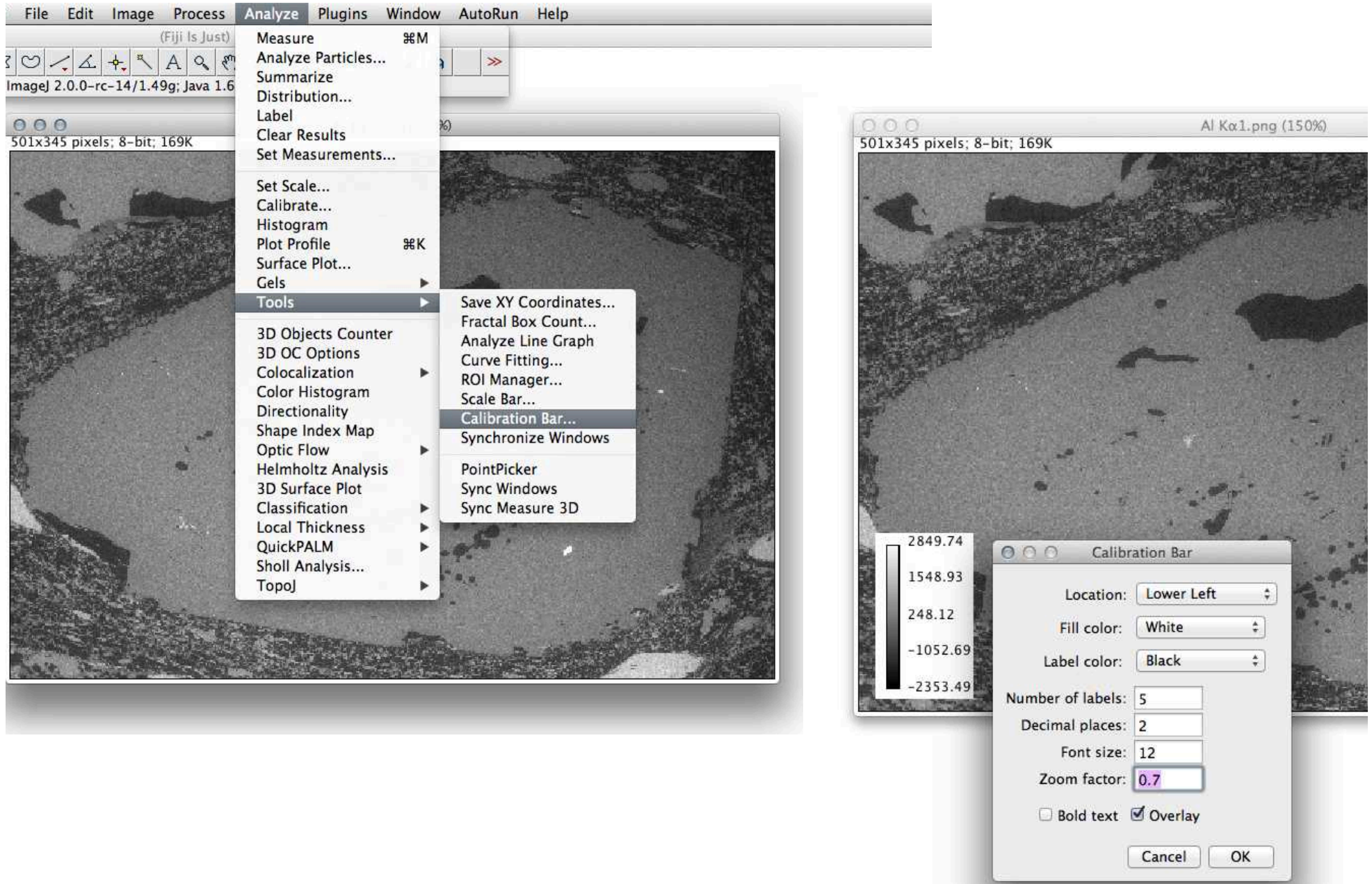
# Calibrate



cmd + m: measure

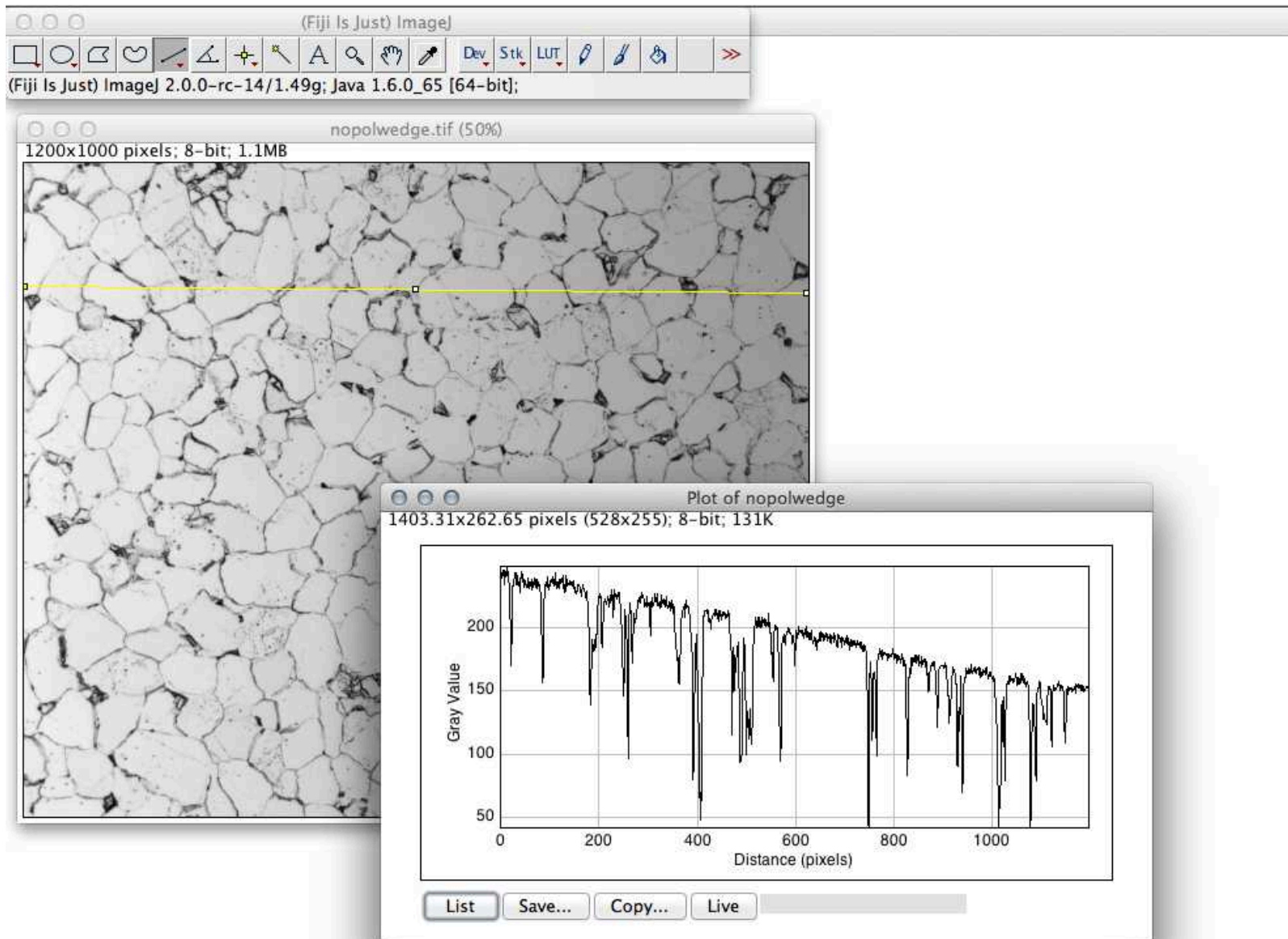


# Calibration bar: z-Skala

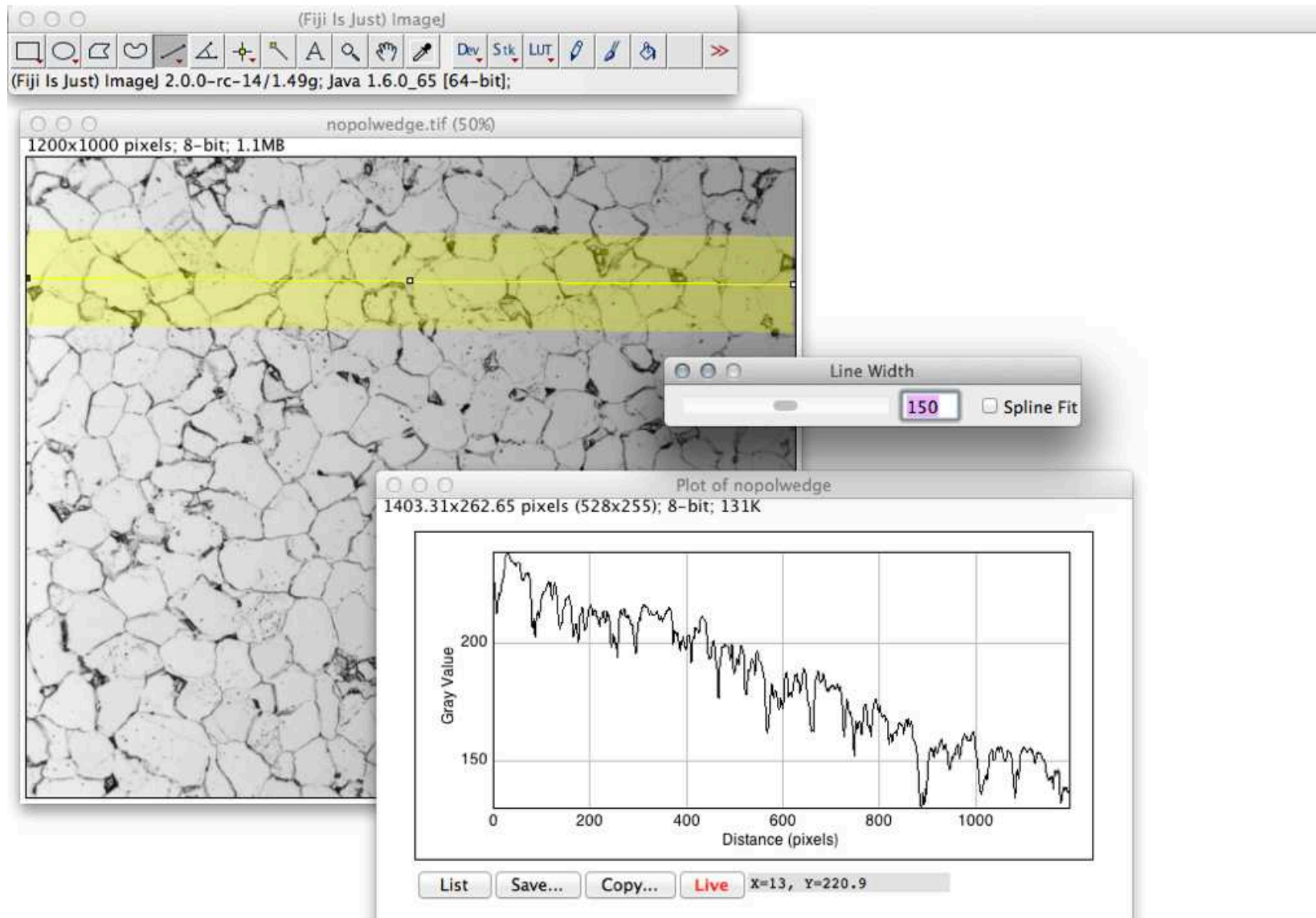


# Hintergrund korrigieren

# Line Profile



# Line Profile



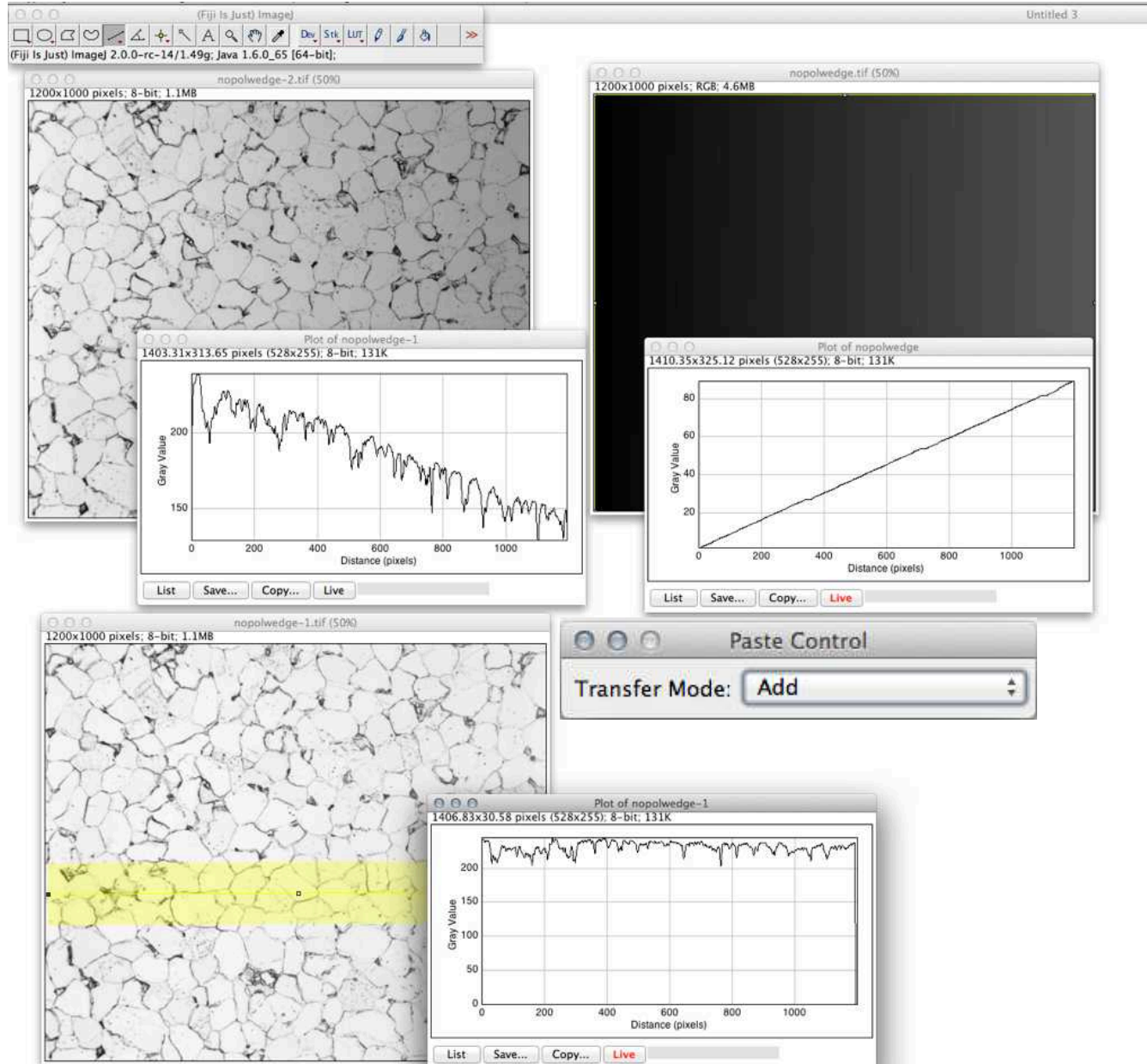


# Hintergrund: manuell

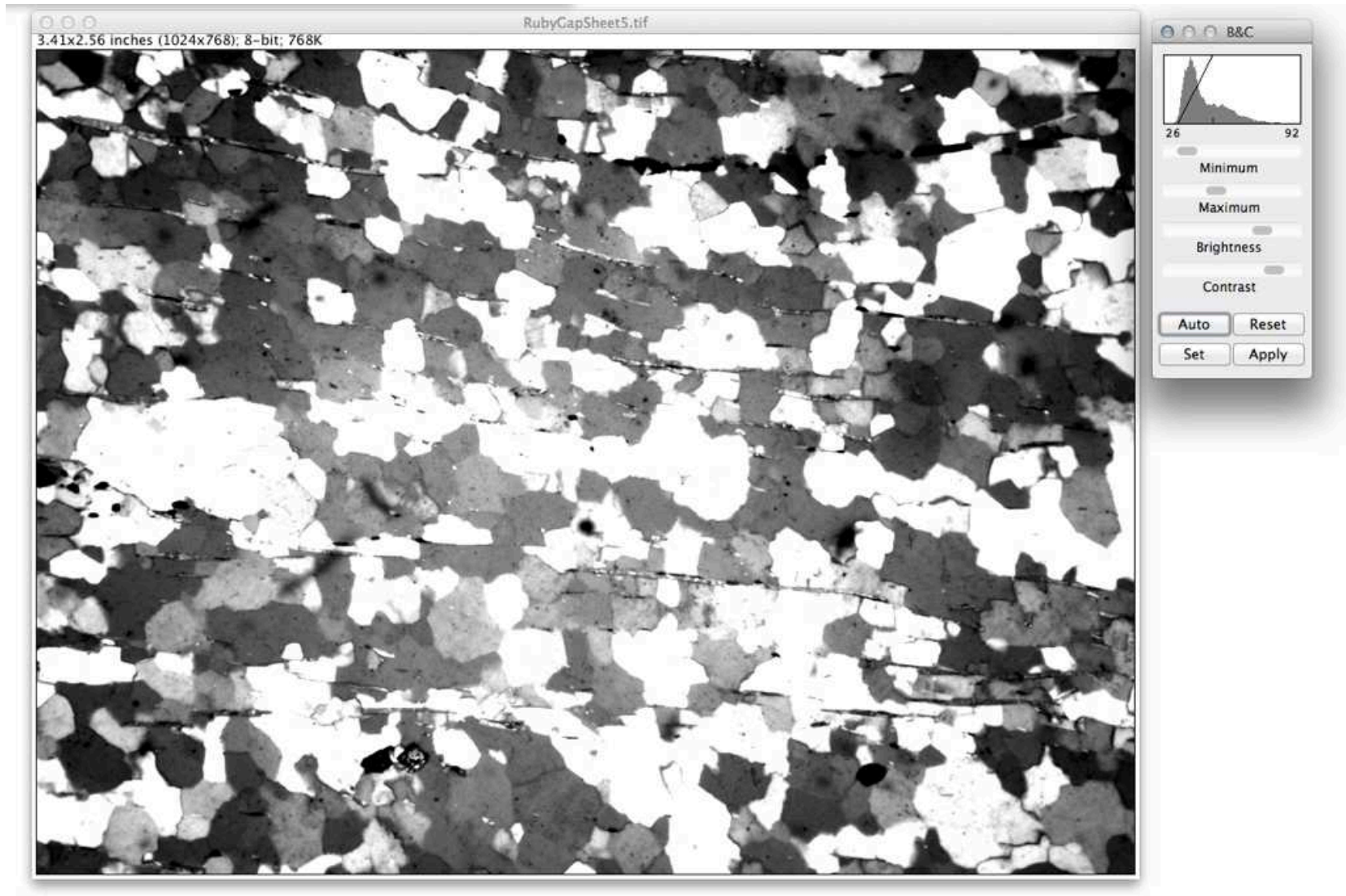
The screenshot displays the Fiji software interface with three main windows and a control panel:

- (Fiji Is Just) ImageJ**: The main application window with a toolbar and status bar.
- nopolwedge.tif (50%)**: A window showing a dark image with a yellow horizontal line drawn across it. The status bar indicates "1200x1000 pixels; RGB; 4.6MB".
- Plot of nopolwedge**: A window showing a line graph of Gray Value vs. Distance (pixels). The status bar indicates "1410.35x325.12 pixels (528x255); 8-bit; 131K". The graph shows a linear increase in gray value from 0 to approximately 80 over a distance of 1200 pixels.
- B&C**: A control panel with a histogram and sliders for Minimum, Maximum, Brightness, and Contrast. It includes buttons for Auto, Reset, Set, and Apply.

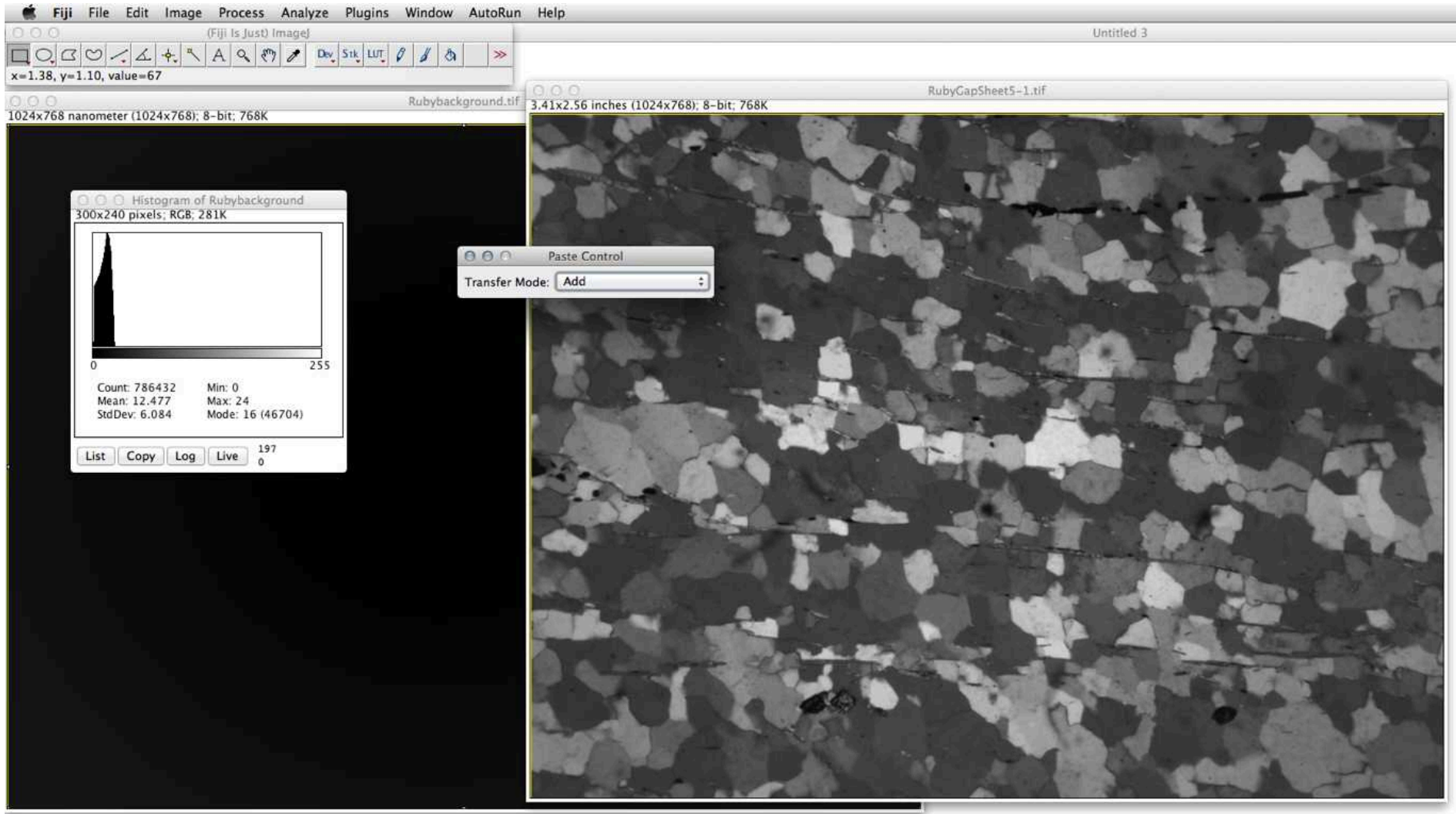
# Hintergrund: manuell



# Hintergrund

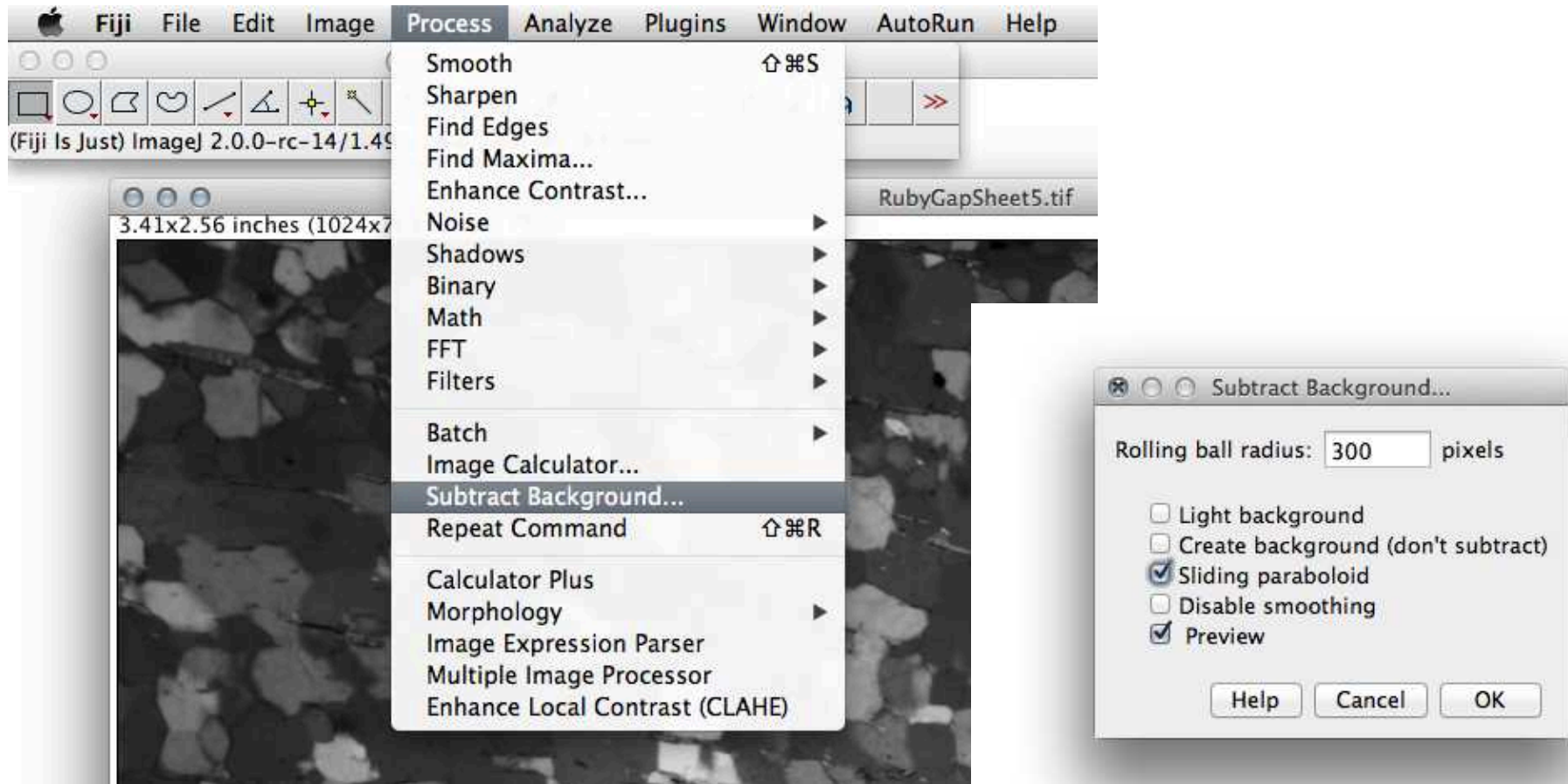


# Hintergrund: bekannter Hintergrund





# Hintergrund: Rolling ball



und wenn man wissen will, wie es gemacht wird:

<http://rsb.info.nih.gov/ij/developer/api/ij/plugin/filter/BackgroundSubtractor.html>

# Übung 7 - Hintergrund korrigieren

Bilder mit inhomogenem Hintergrund (Beleuchtung) korrigieren.

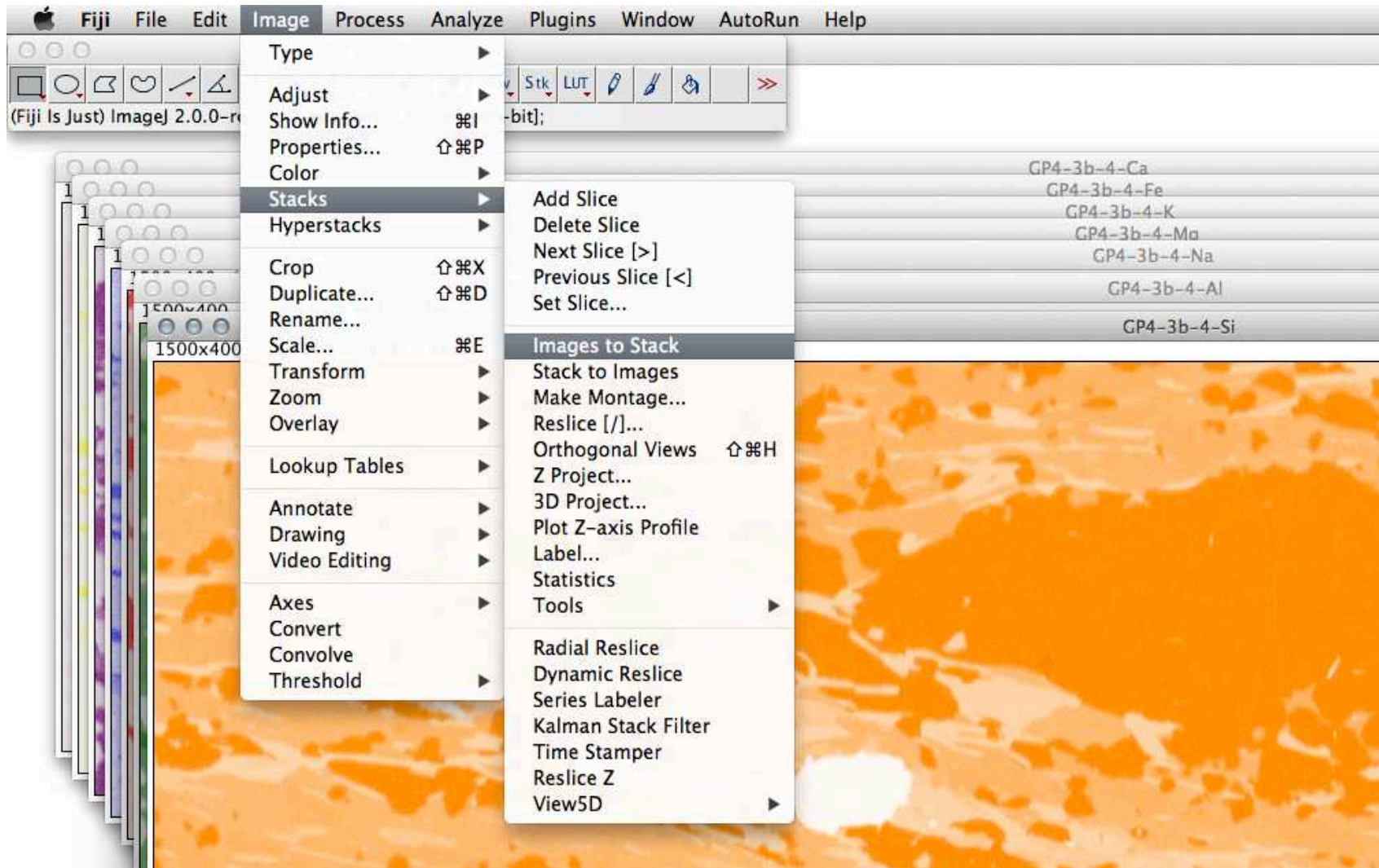
■ Öffnen Sie die Bilder 'Al K&I.png', 'nopolwedge.tif' und 'RubyGapSheet5.tif' im Ordner Background.

Korrigieren sie die Hintergründe.

Wie gehen Sie vor ?

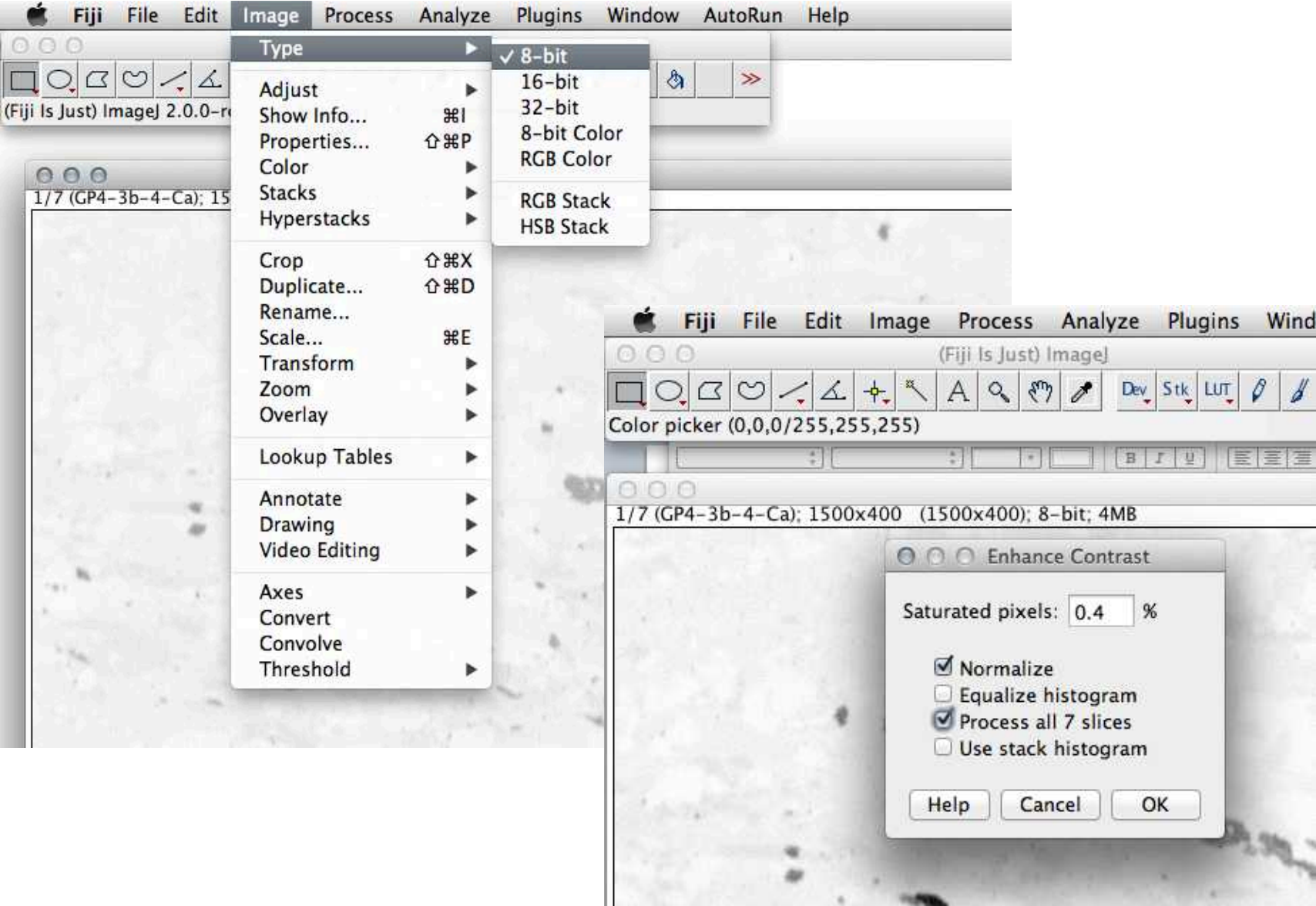
# RGB Stacks

# Stacks

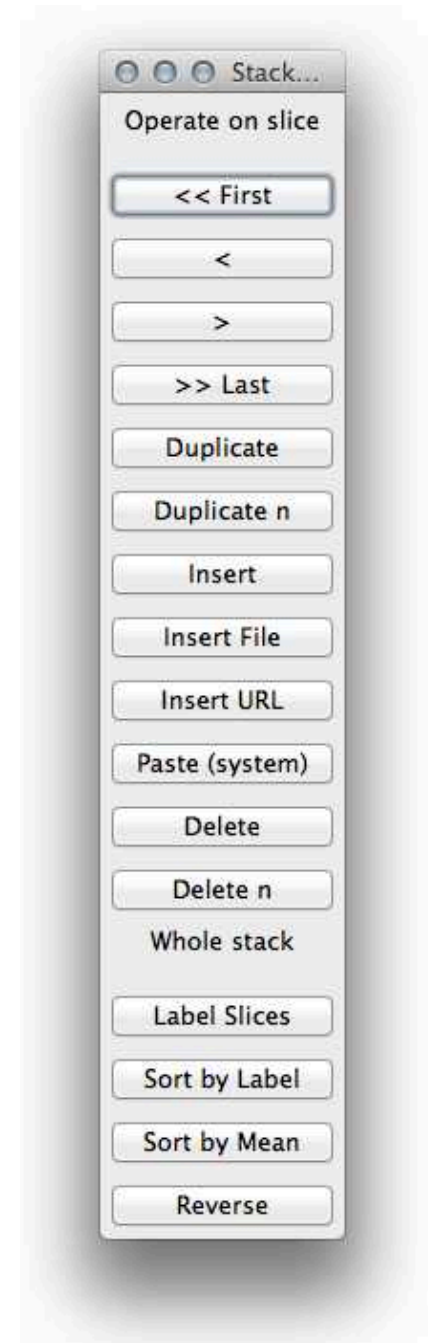
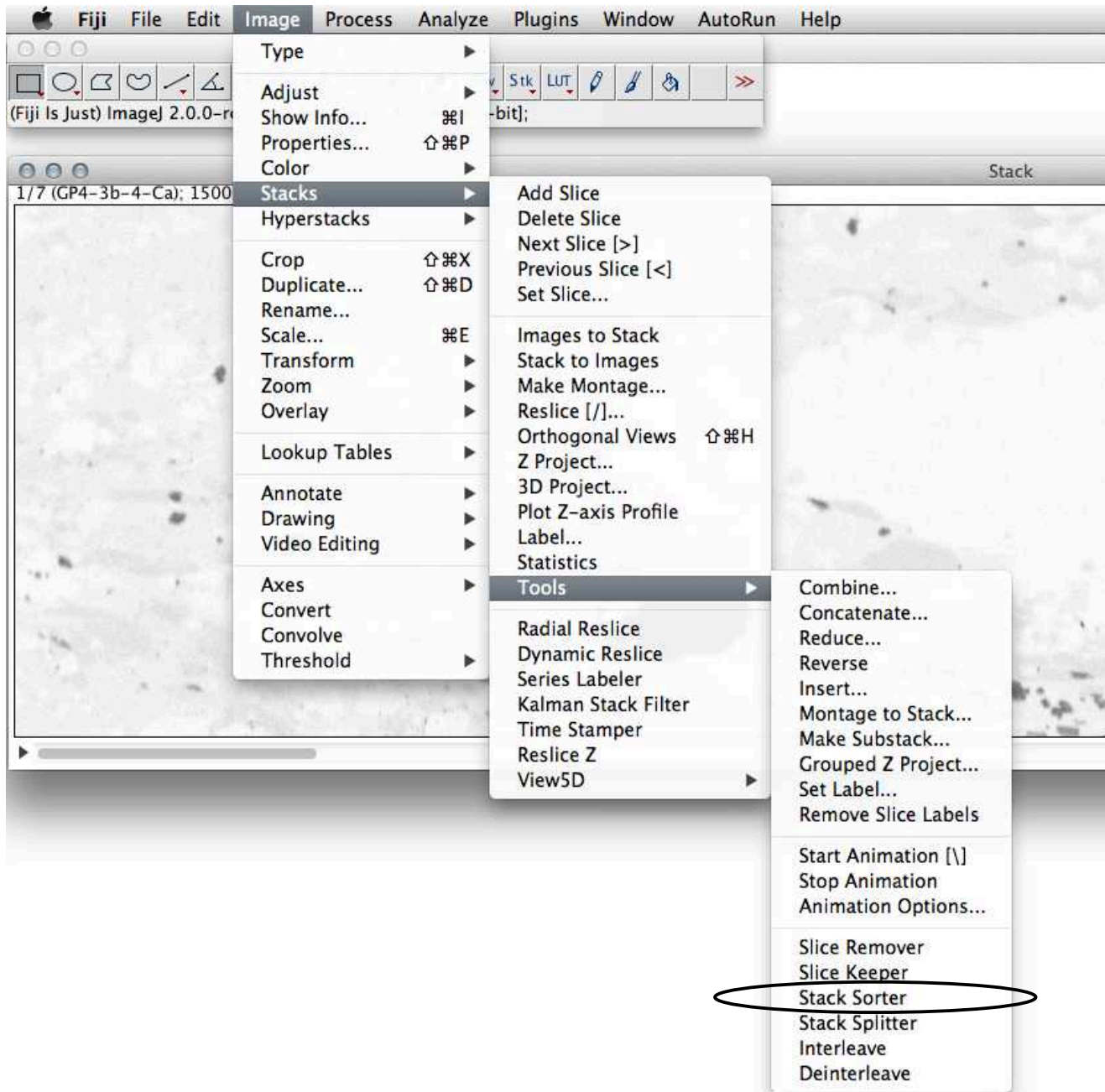




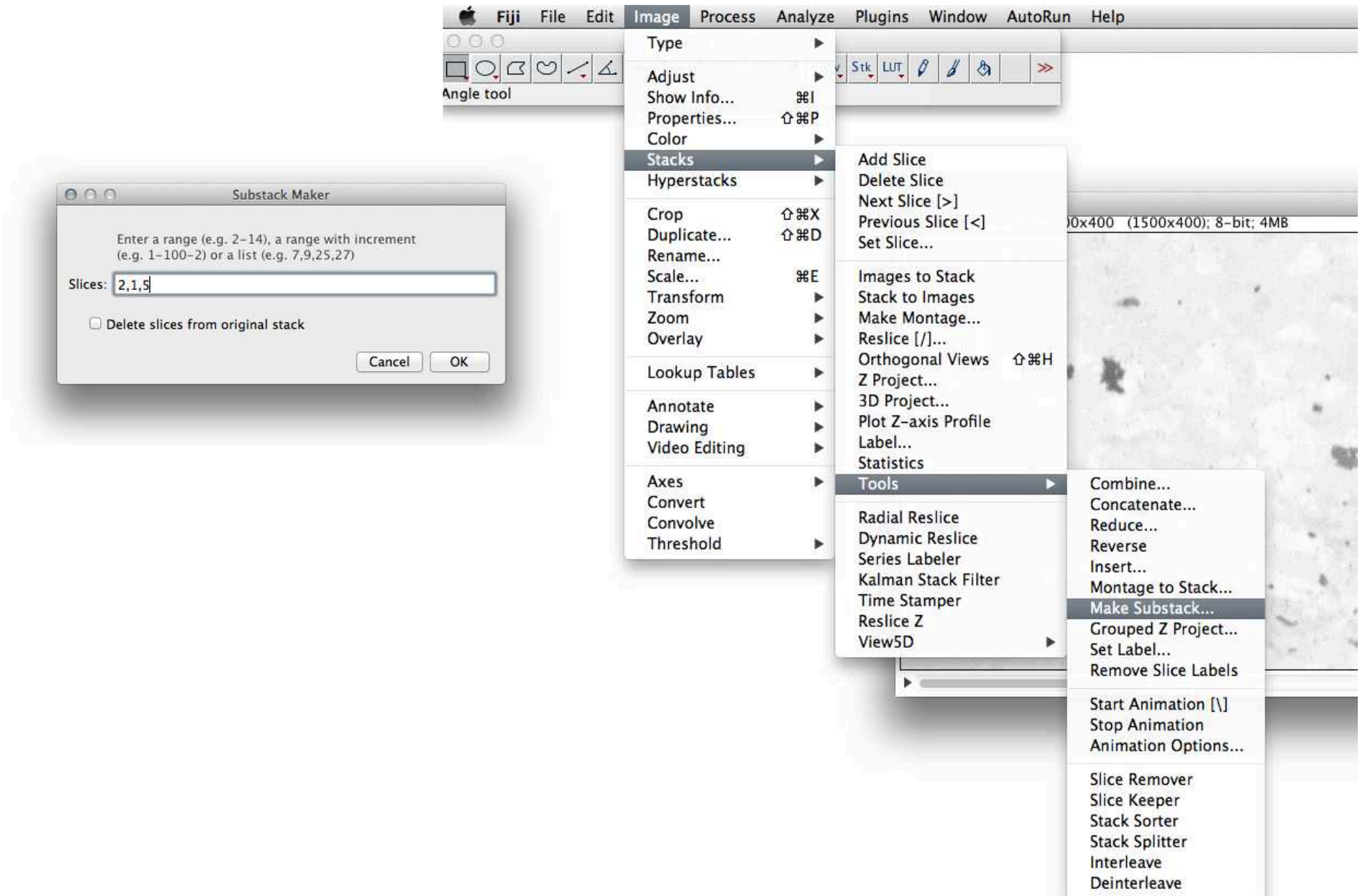
# Stacks: Stack operations



# Stacks: Tools

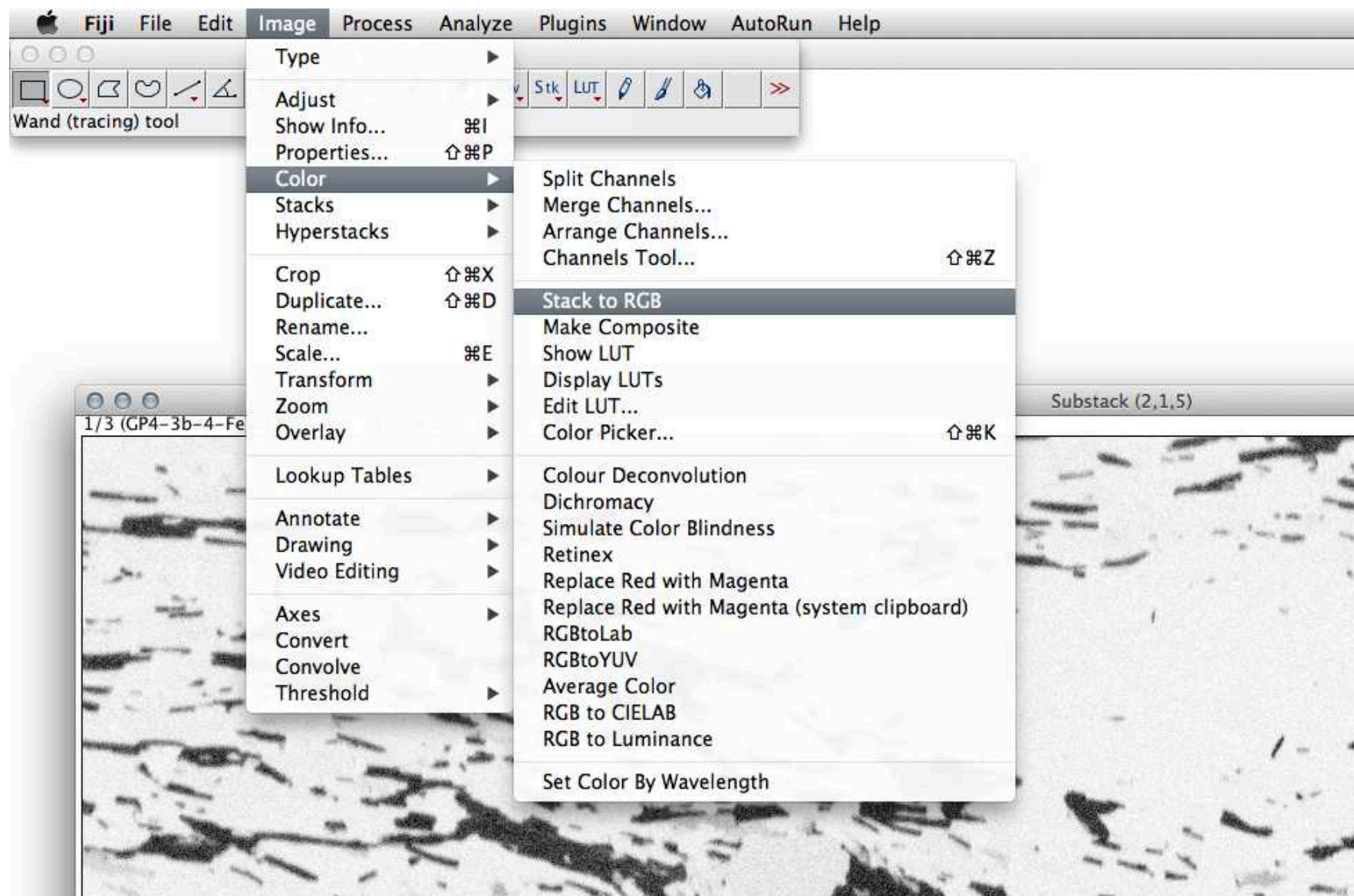


# Stacks: Substacks





# Stacks: RGB images





# Übung 8 - Verteilungsbilder (RGB)

Von Element-Verteilungskarten zu Mineralphasen

■ Die Element-Verteilungsbilder aus dem Ordner GP4\_edx öffnen.

Hohe Counts in den edx Bildern erscheinen hell.

Aus jeweils drei (sinnvoll auszuwählenden) Element-Verteilungsbildern sind Phasenverteilungsbilder herzustellen.

Quarz	$\text{SiO}_2$
Kalifeldspat	$\text{KAlSi}_3\text{O}_8$
Plagioklas	$\text{Na}_{0.8}\text{Ca}_{0.2}\text{Al}_{1.2}\text{Si}_{2.8}\text{O}_8$
Biotit	$\text{K}(\text{Fe},\text{Mg})_3\text{AlSi}_3\text{O}_{10}\text{OH}_2$
Muskovit	$\text{K}(\text{Al})_2\text{AlSi}_3\text{O}_{10}\text{OH}_2$

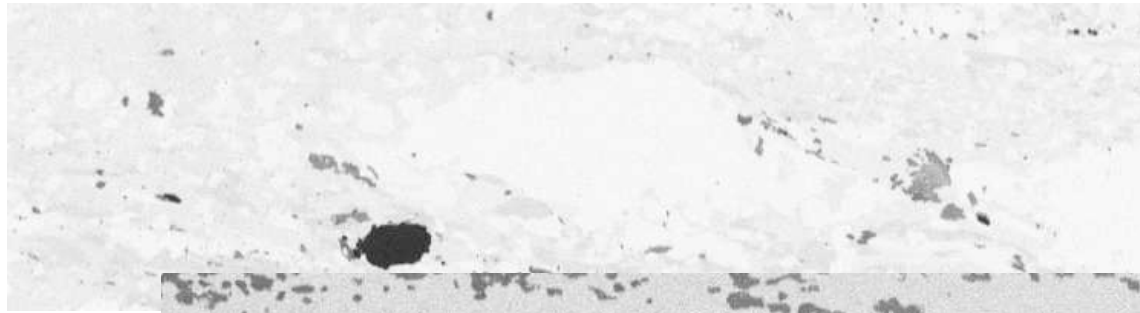
(1) Stellen Sie ein Phasenverteilungsbild her, in welchem Quarz rot erscheint.

(2) Stellen Sie ein Phasenverteilungsbild her, in welchem Quarz schwarz erscheint, und möglichst viele Phasen unterschieden werden können.

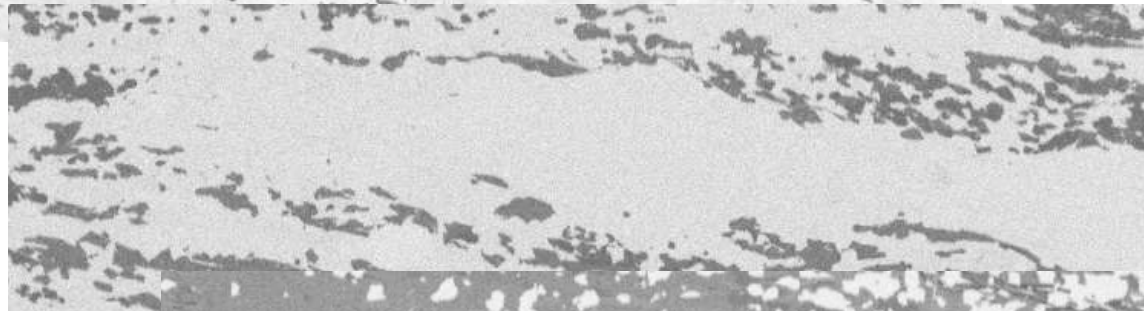
Tipp: erst einzelne Element-Bilder kombinieren (z.B. addieren).

# Beispiel

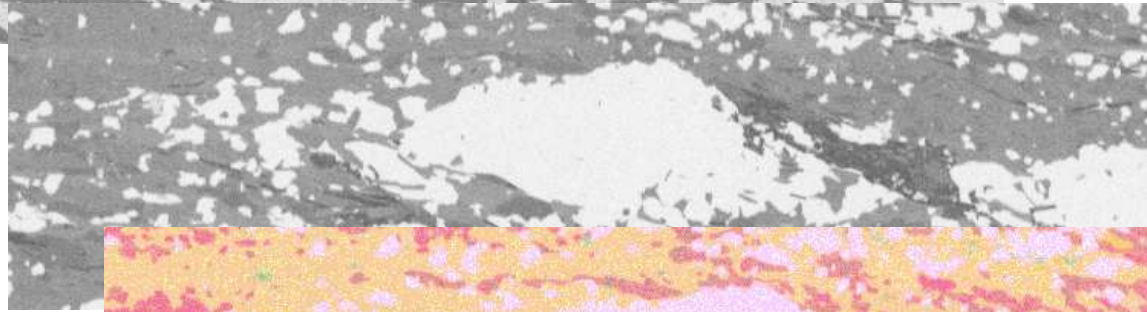
Rot = Ca



Grün = Al



Blau = Na



RGB (Positiv)



Achtung: Die Element-Bilder sind invertiert.

# DBA 2014


## session 4

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
→ URZ - Universitätsrechenzentrum  
→ VIA - Vorlesungsverzeichnis  
→ PERSSEARCH - Personensuche

HOME Contact Studium Geowissenschaften Lehrveranstaltungen Vorträge und Links Strukturgeologie  
Rock Deformation Projects & Software Workshops Textbook DDM Macros ImageJ Macros ImageJ Kiviat

LEHRVERANSTALTUNGEN



...le ciel n'est pas "L'appel des cimes" de René Magritte...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehölle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageEXM bzw. ImageJ kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageEXM software (Mac/OSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Exportation (2-D -> 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software Image EXM, bzw. ImageJ (alle public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungbestellung möglich)
- Harterter, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET** [earth.unibas.ch](http://earth.unibas.ch)  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

TROMSØ GEOIMAGING

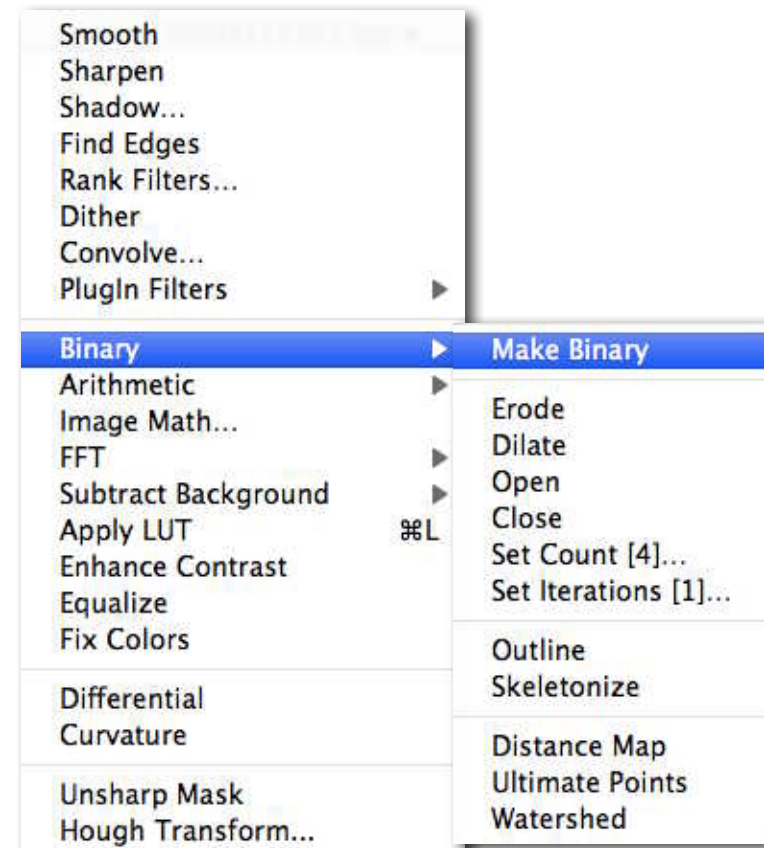
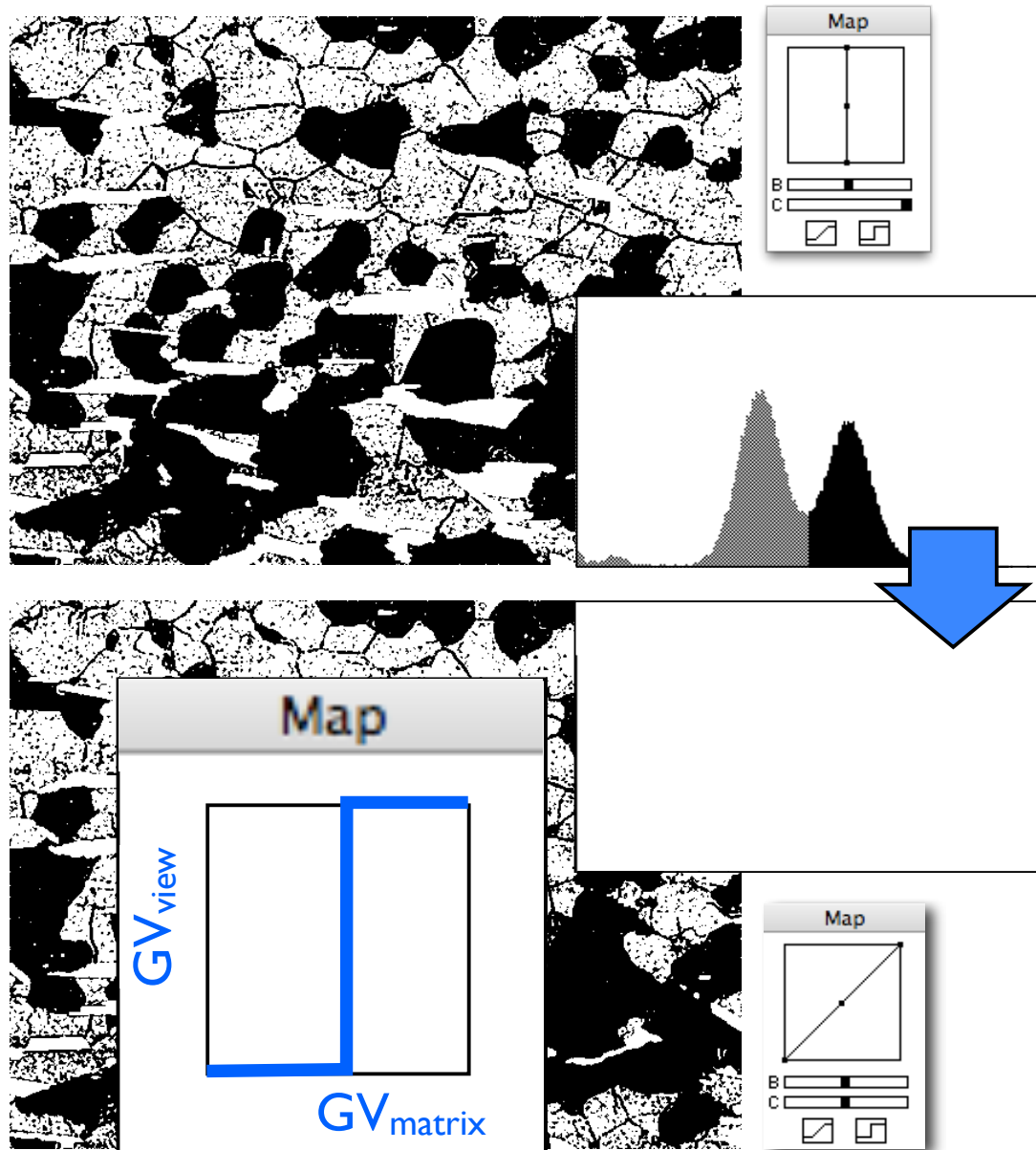
→ TROMSØ CRISTAL DYNAMICS HOMEPAGE (English)  
→ TROMSØ GEOLOGY HOMEPAGE (Norwegian)  
→ TROMSØ UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>

# LUT & POP segmentation

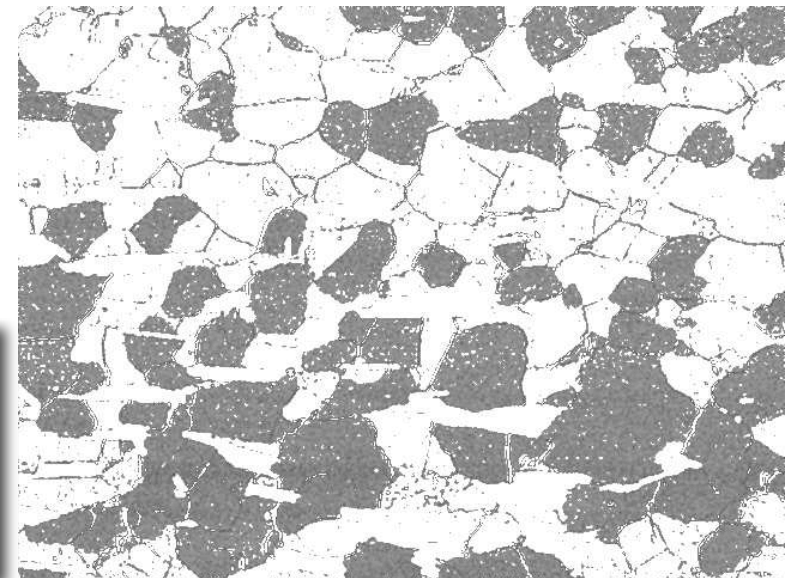
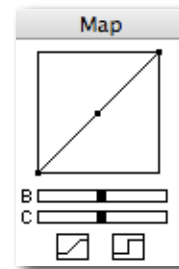
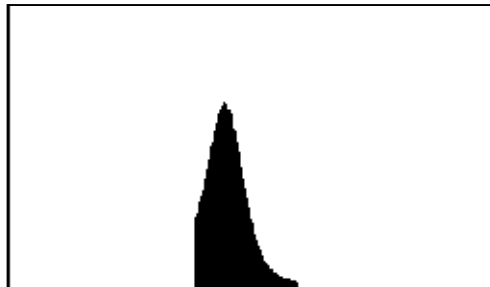
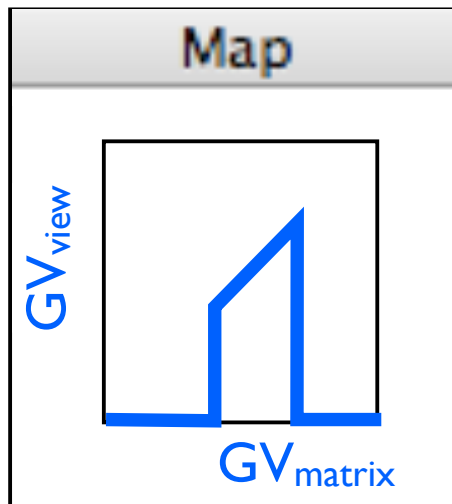
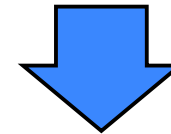
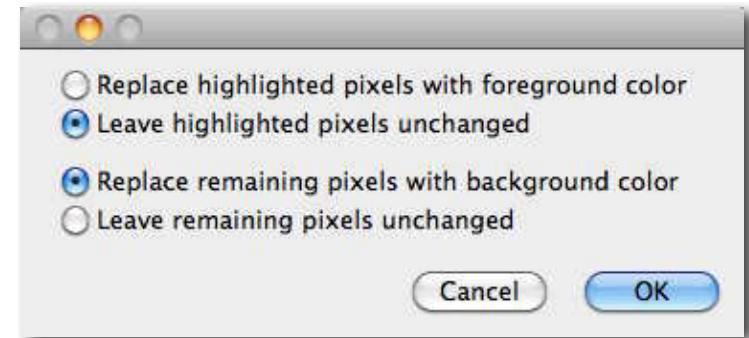
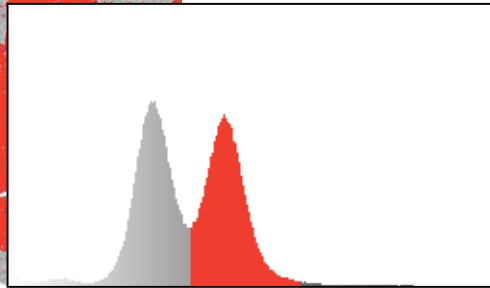
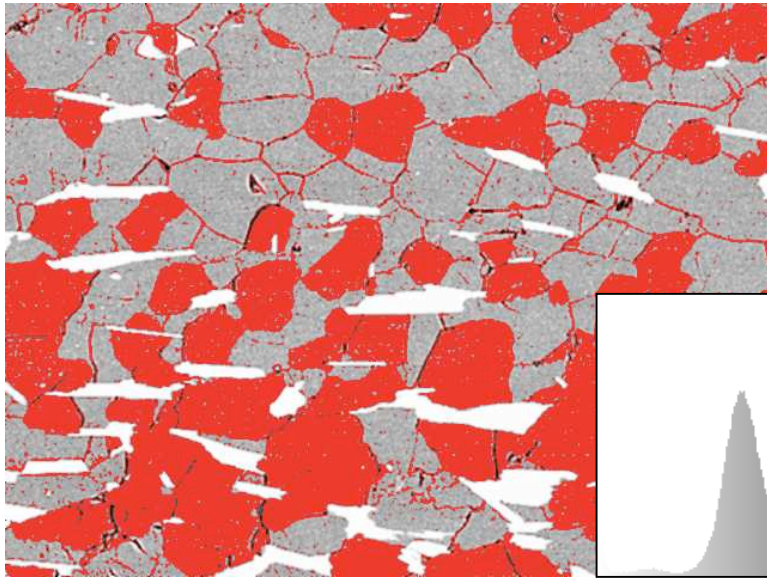


# LUT to POP - Threshold



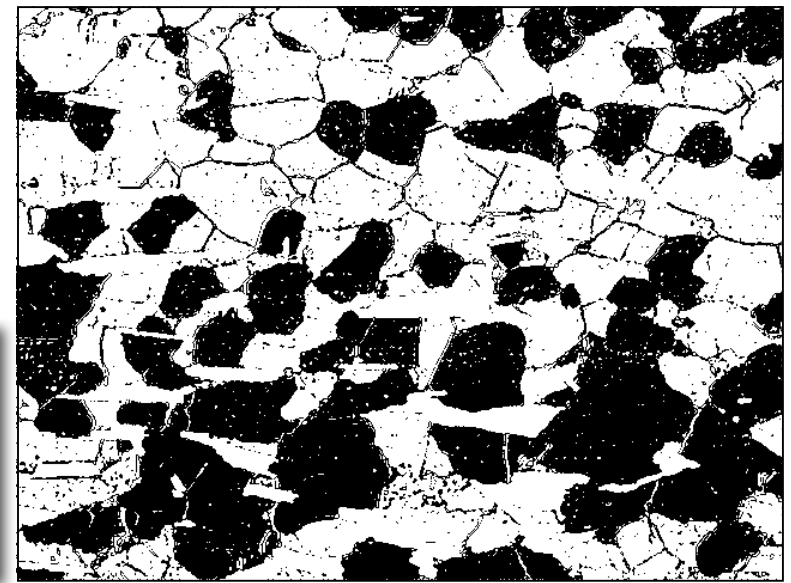
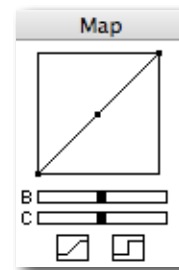
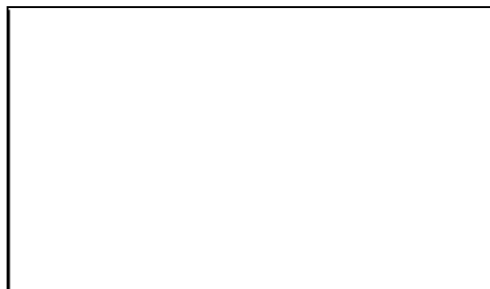
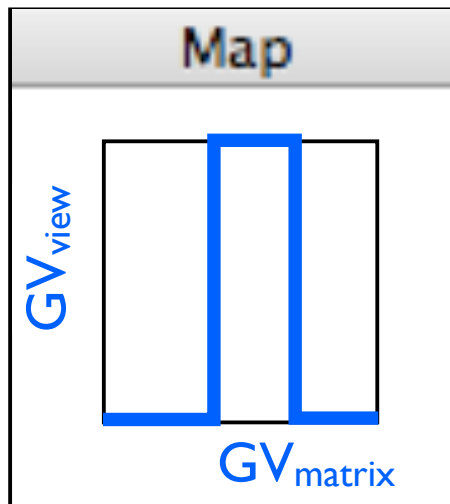
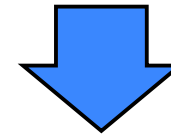
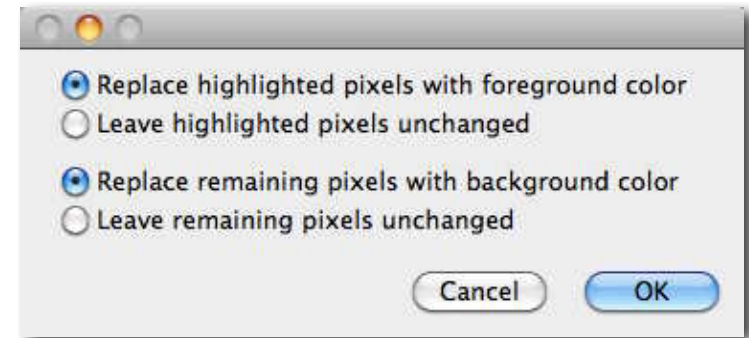
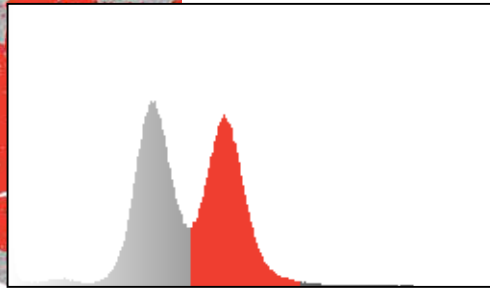
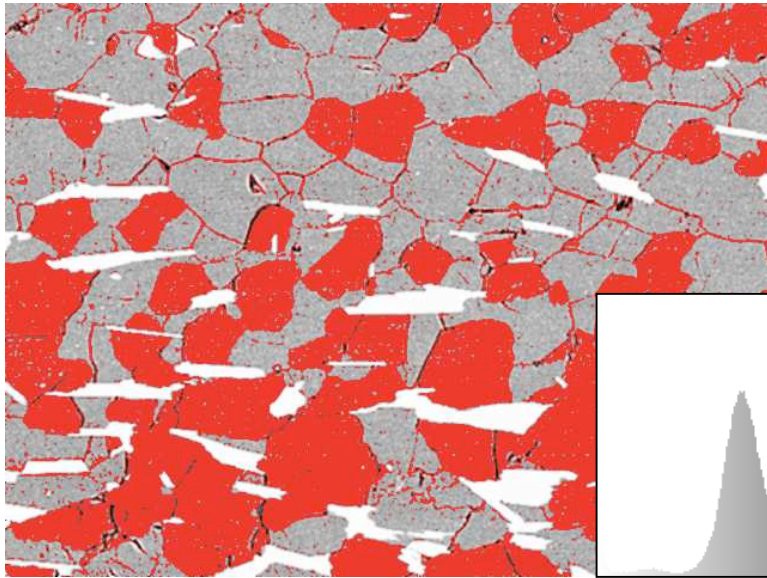
# LUT to POP - Density Slice

Apply LUT (⌘L) - SXM only



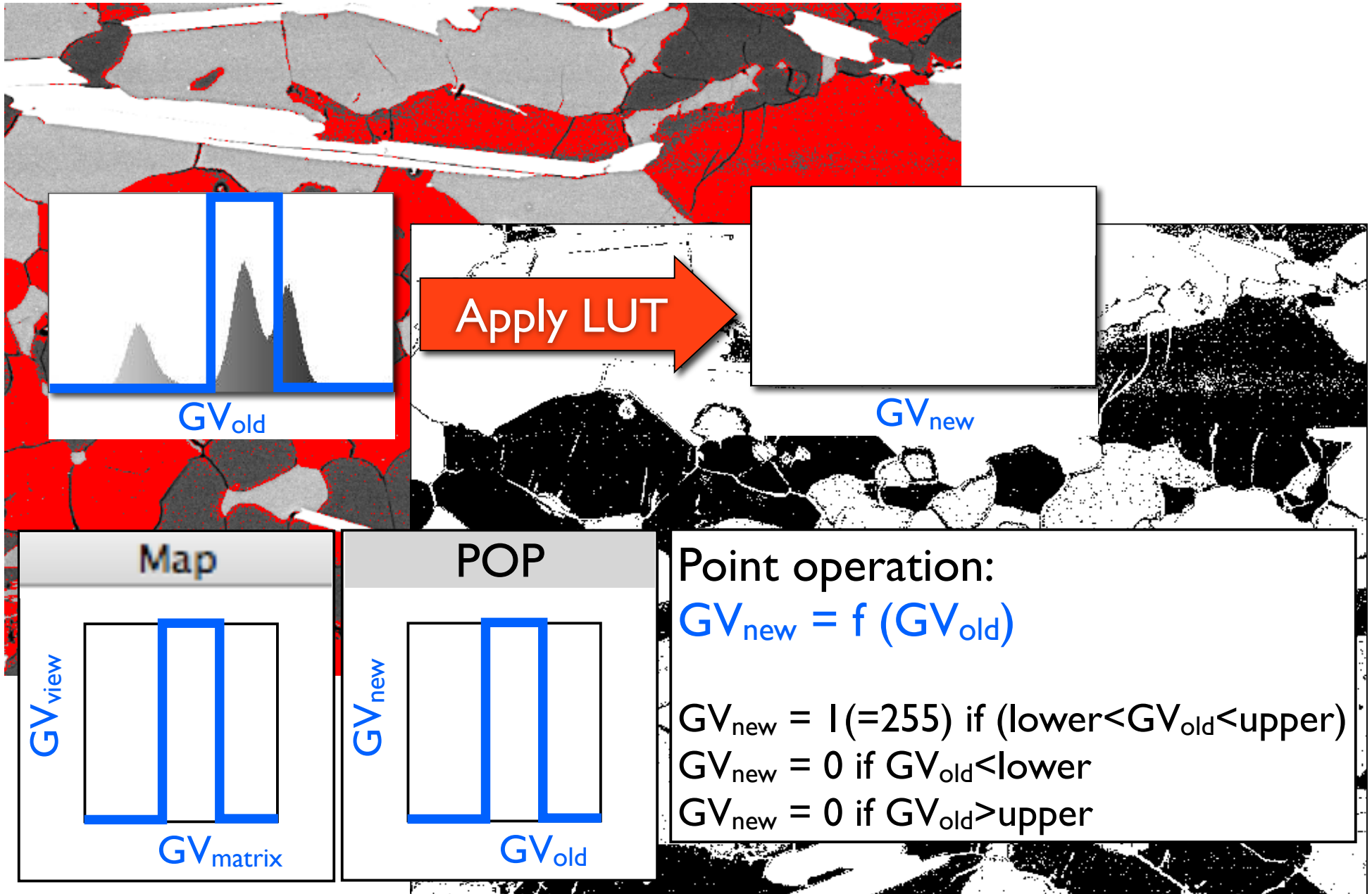
# LUT to POP - Density Slice

Apply LUT (⌘L) - SXM only





LUT  $\rightarrow$   $GV_{new} = f(GV_{old}) \rightarrow$  POP





**pre-process**  
**look at the data**

detail of mylonitic granite

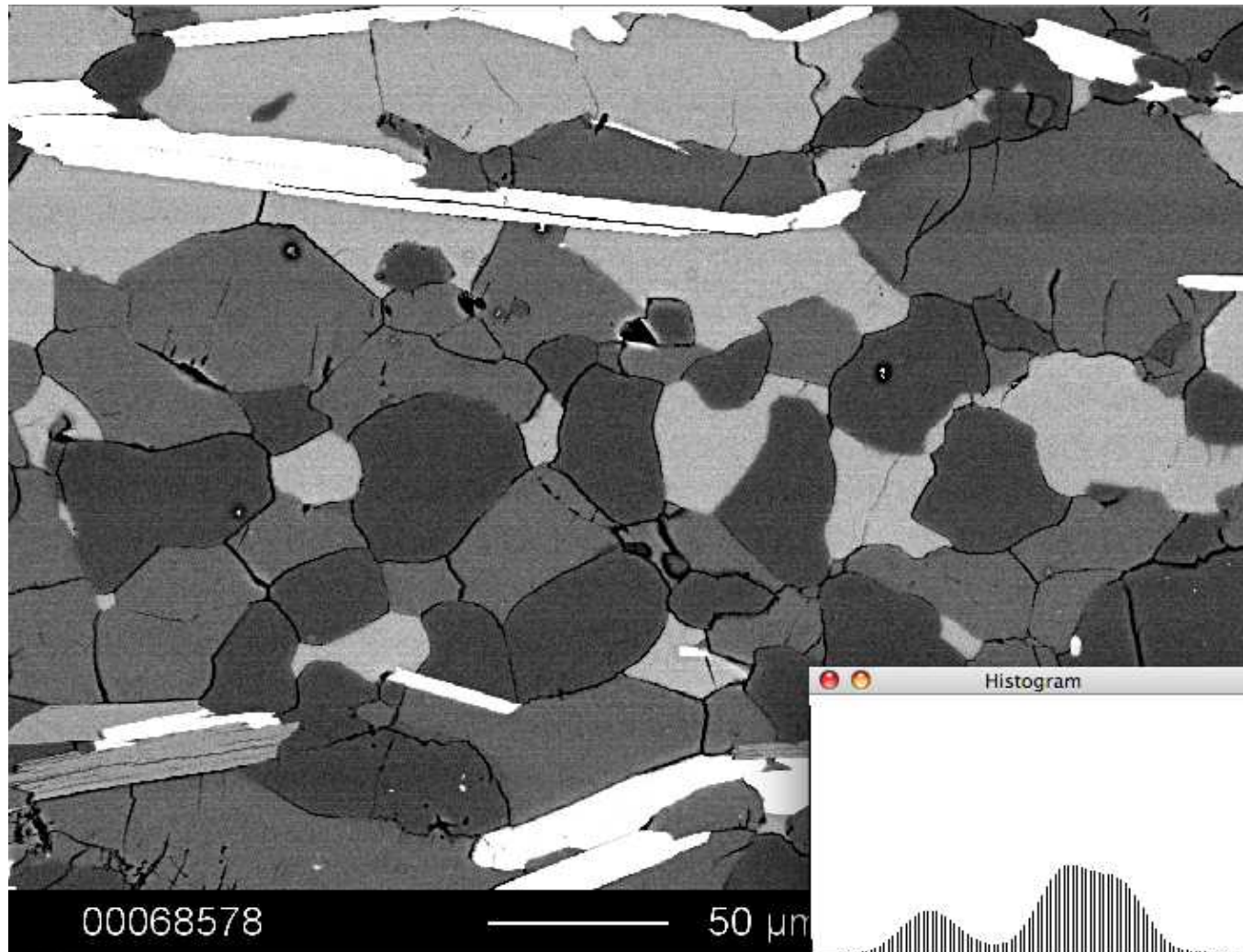
image size: 1424 x 1080 px

resolution: 100 grey values (of 256)

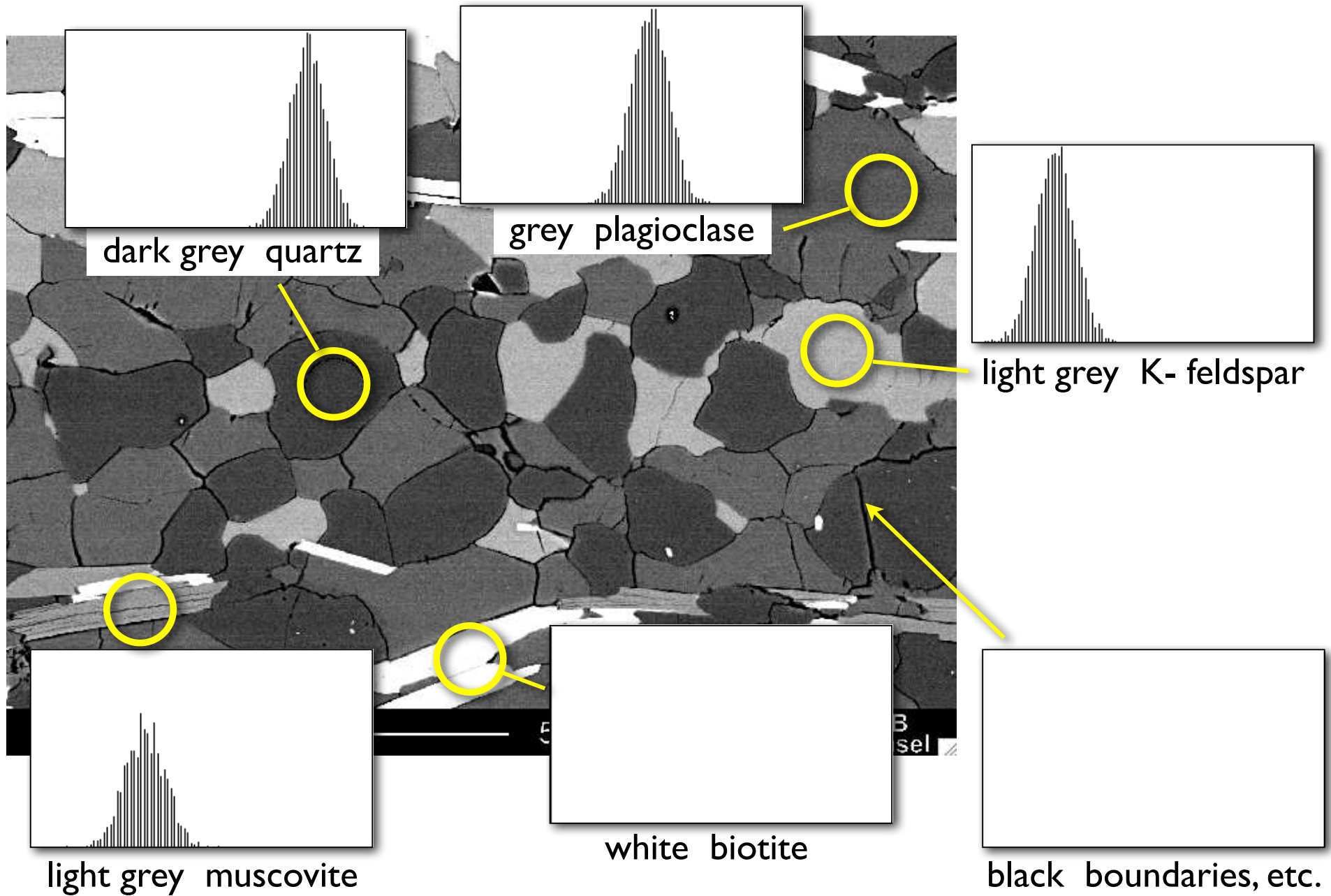
SEM / BSE contrast

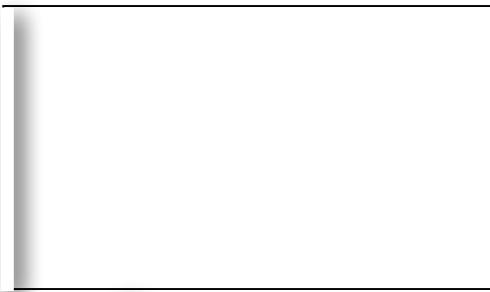
1px = 0.24  $\mu\text{m}$

~7 bit



micrograph of mylonitic granite (Truzzo) 1424 x 1080 pixel  
SEM / Back scatter electron contrast

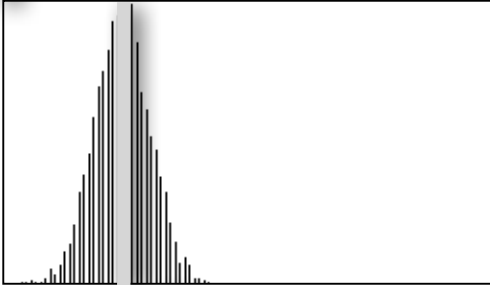




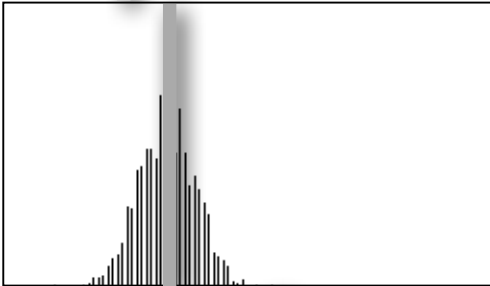
1 - biotite



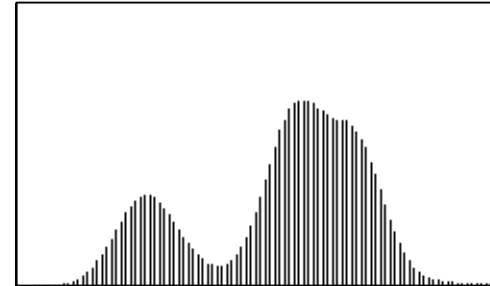
6 - boundaries, holes, etc.



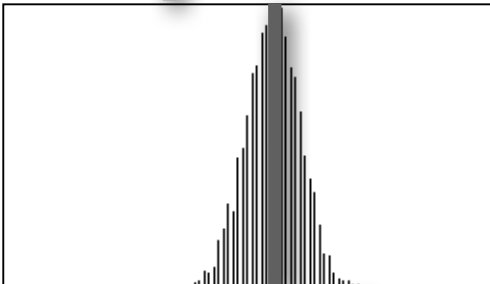
2 - K- feldspar



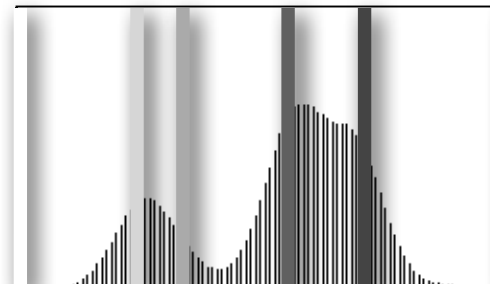
3 - muscovite



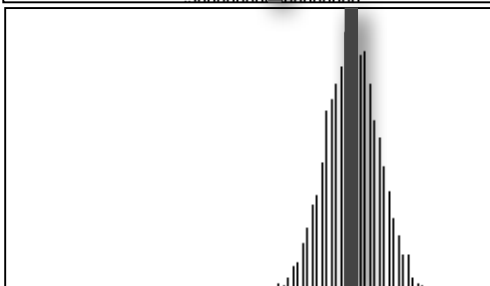
all phases



4 - plagioclase



all phases



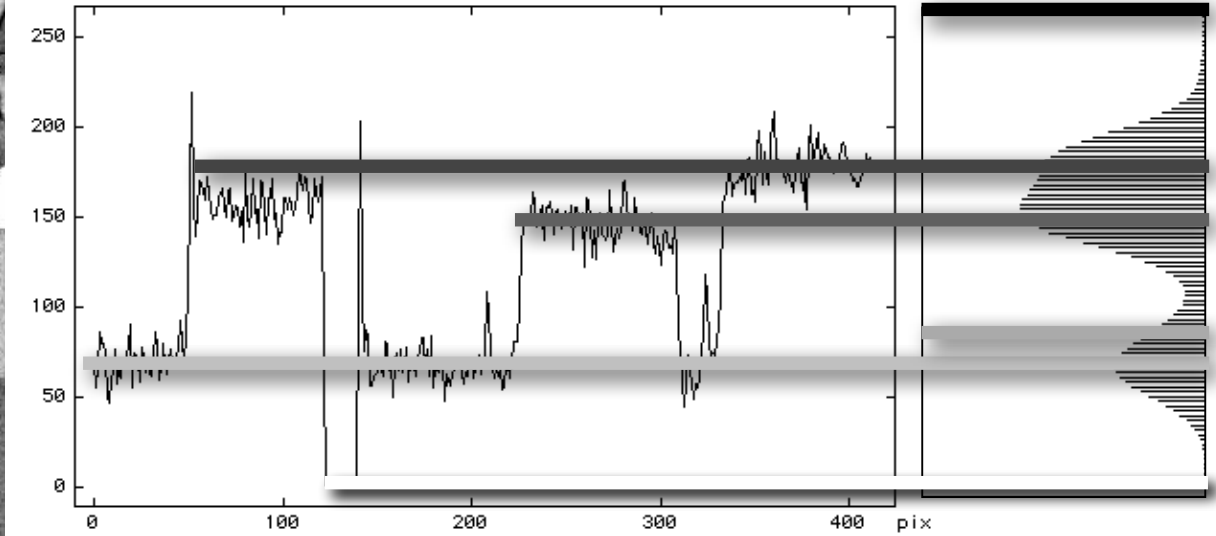
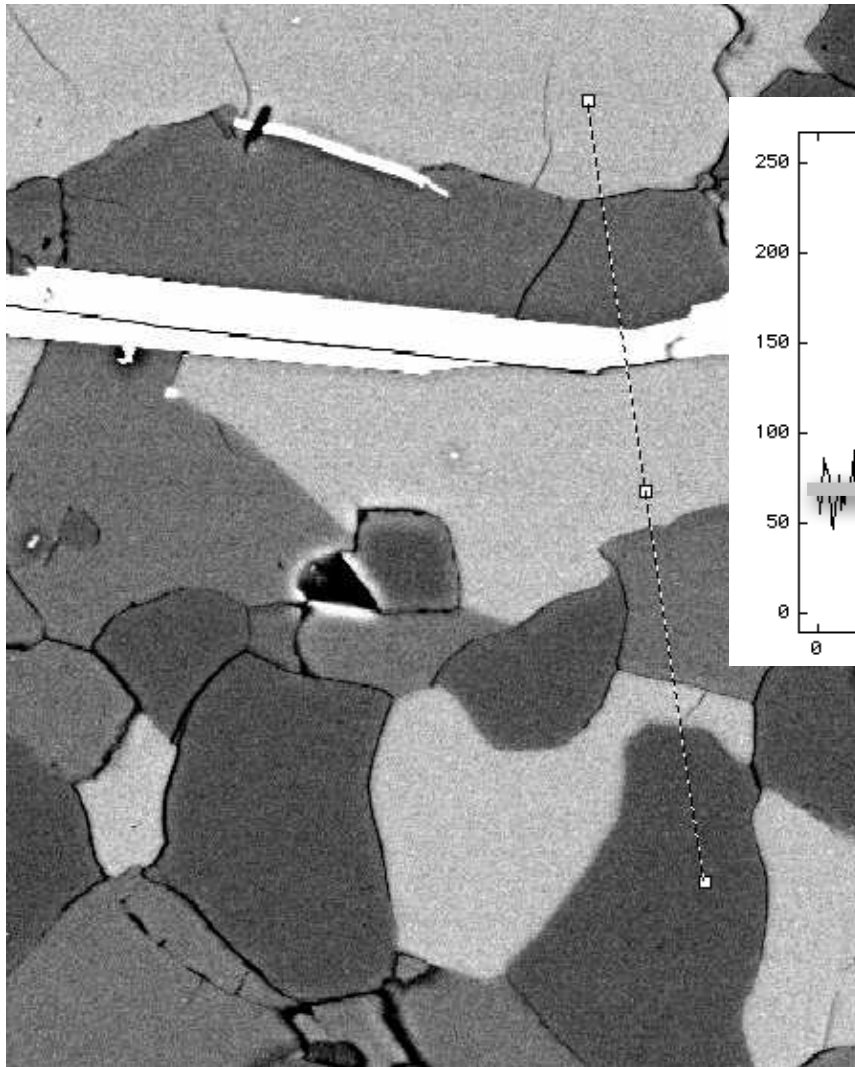
5 - quartz

1 2 3 4 5 6



# Profiles

6 - boundaries,  
holes, etc.



5 - quartz

4 - plagioclase

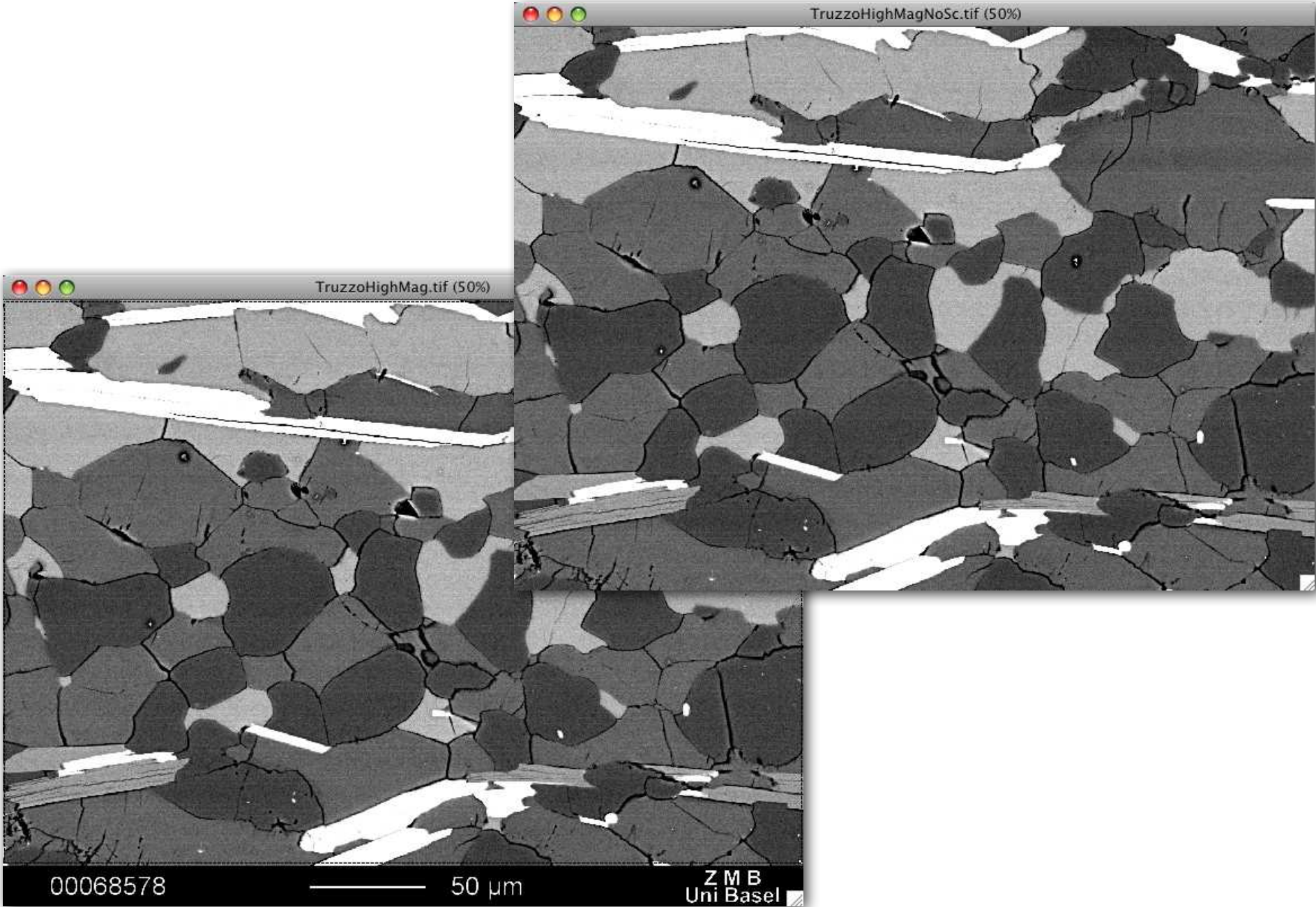
3 - muscovite

2 - K- feldspar

1 - biotite

**pre-process  
noise removal**

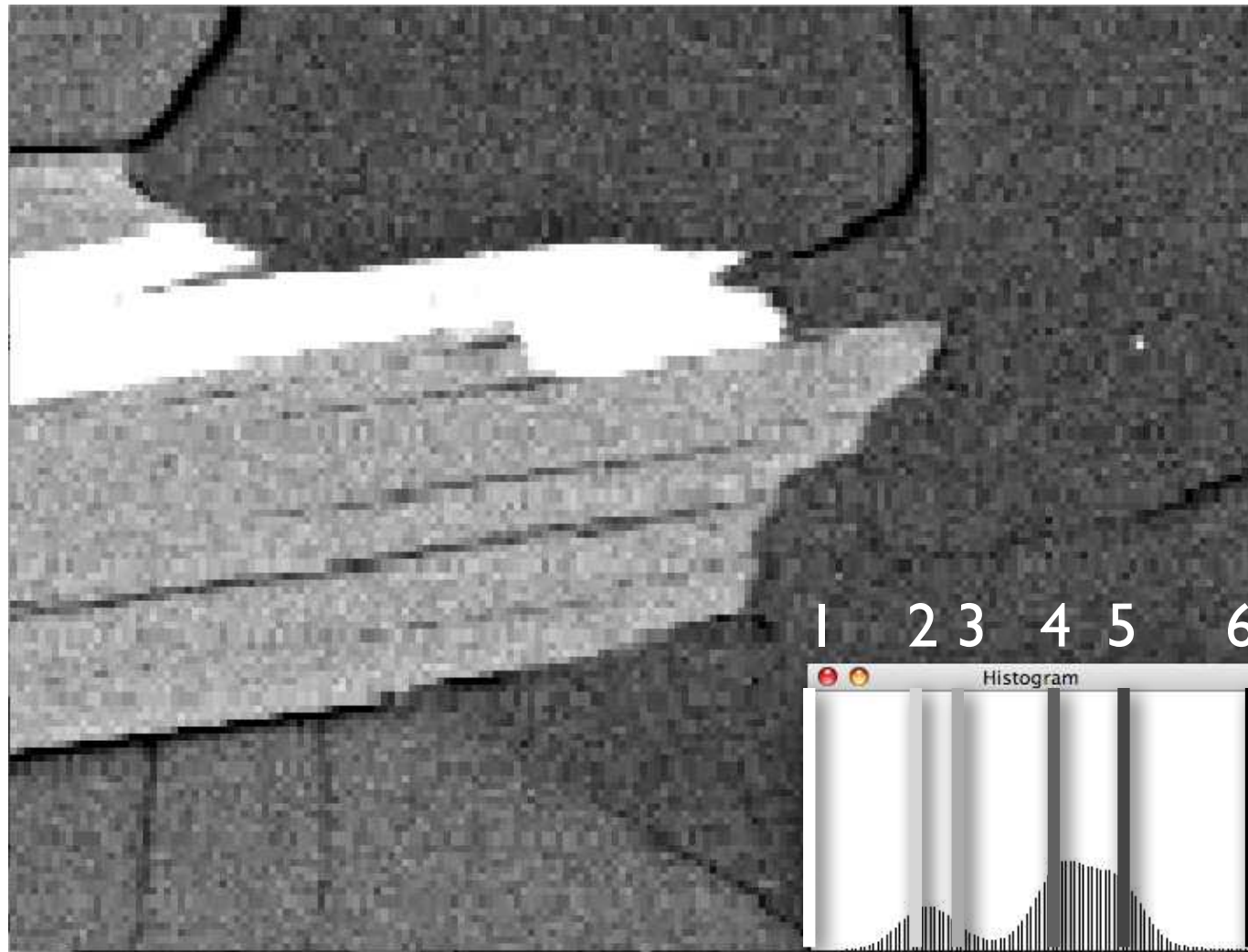
# pre-process: extract region of interest (ROI)



as recorded

SEM scanning artifact

detail  
( 8x )



1 - biotite

3 - muscovite

5 - quartz

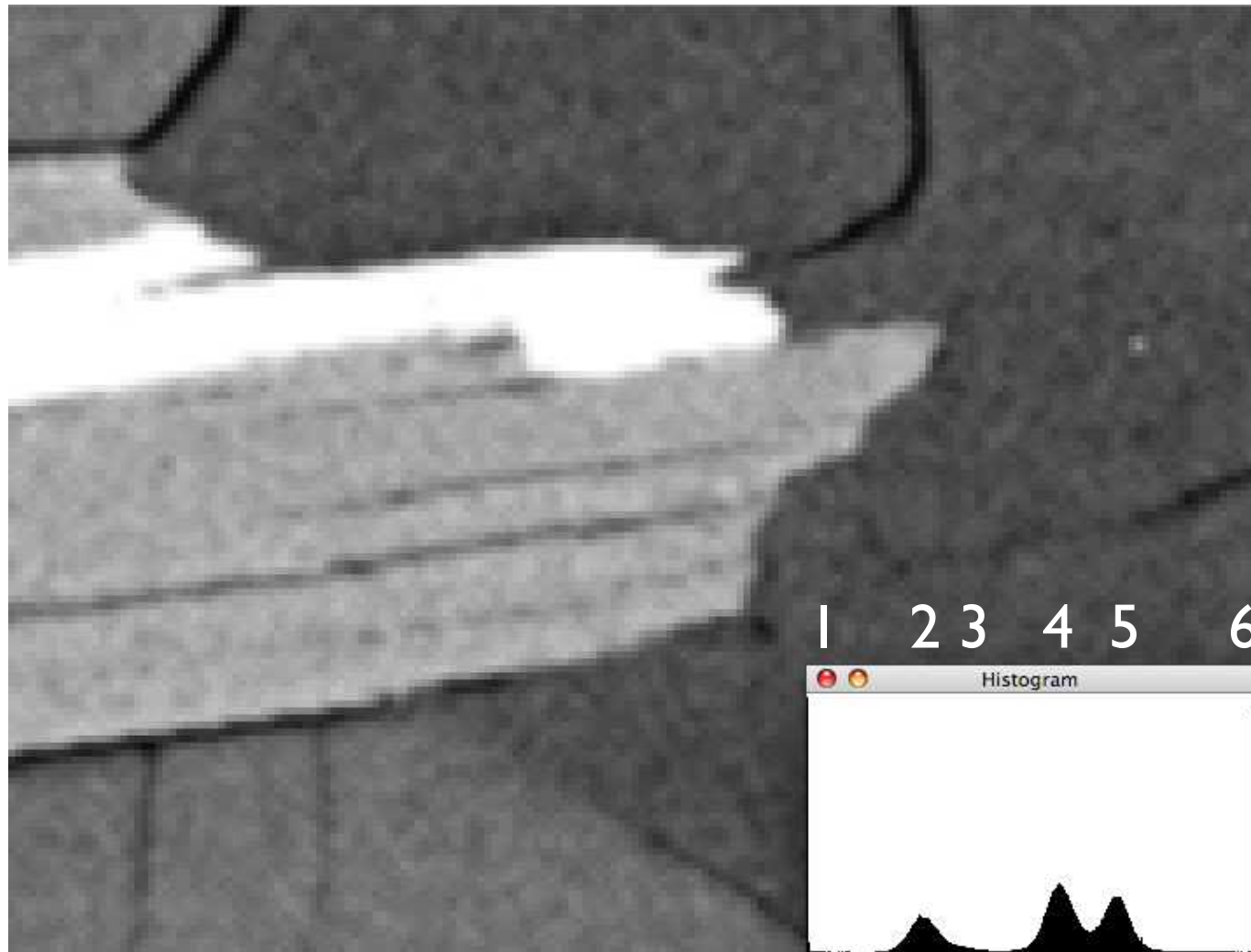
2 - K- feldspar

4 - plagioclase

6 - boundaries, holes, etc.

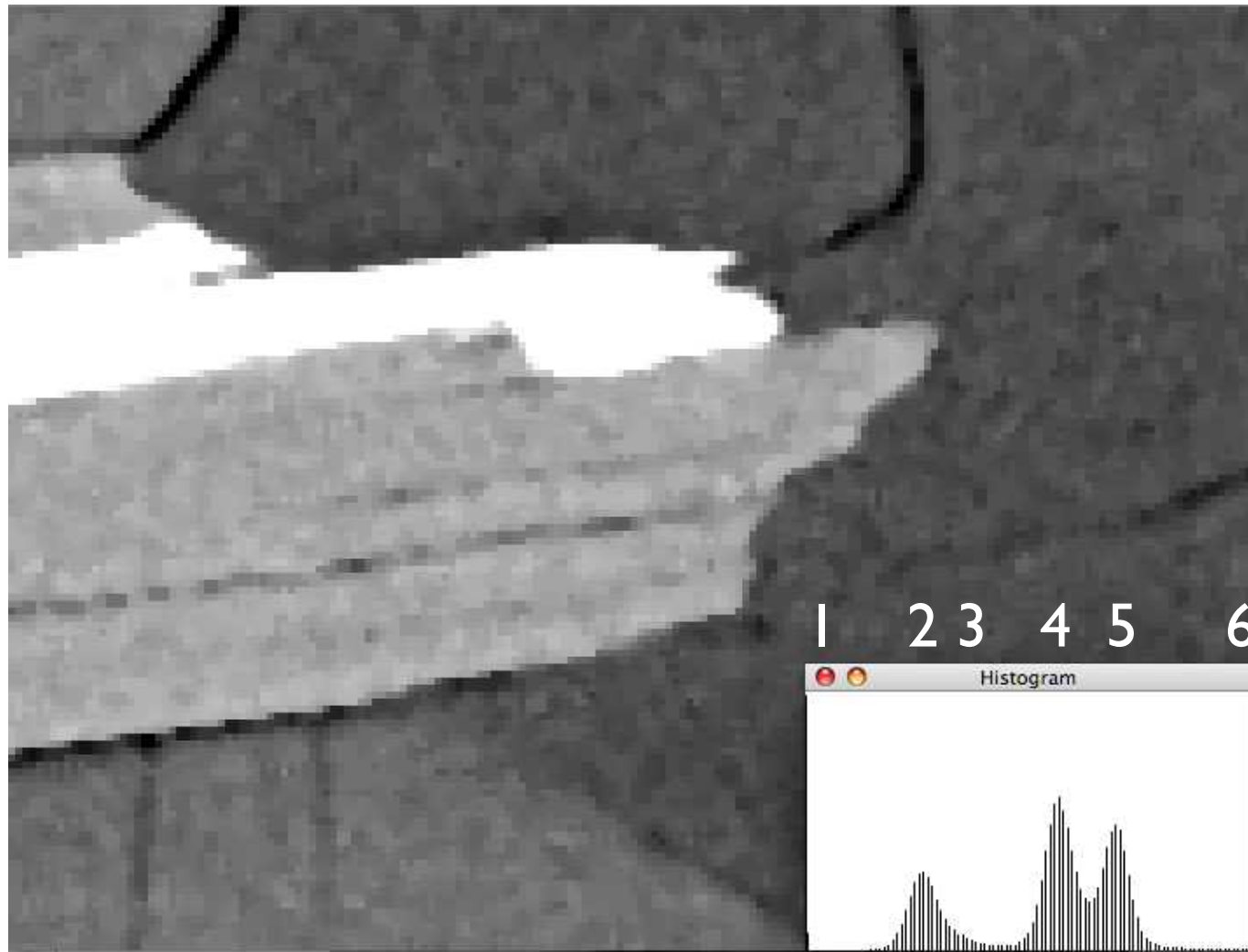


# smoothing



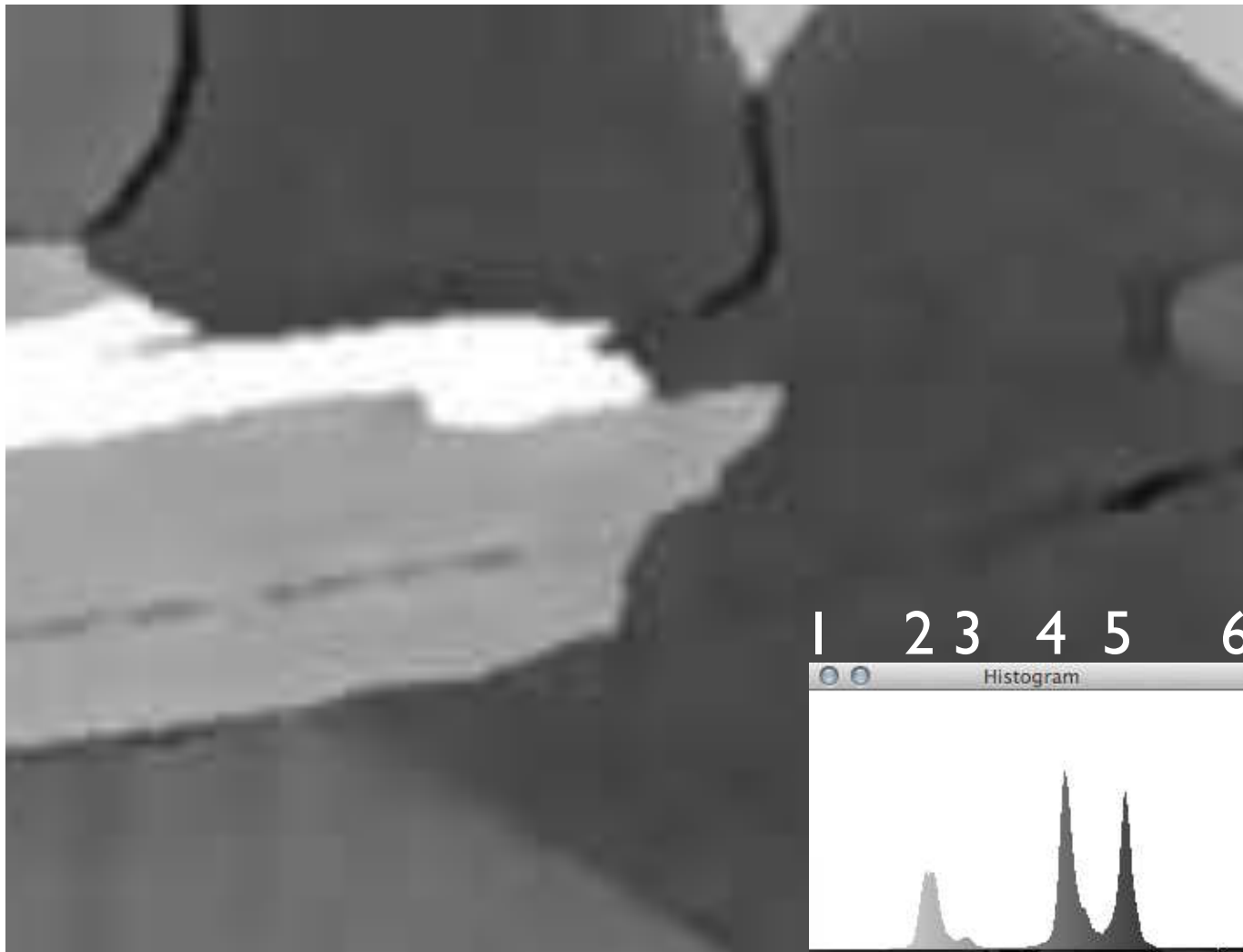
- |                 |                 |                             |
|-----------------|-----------------|-----------------------------|
| 1 - biotite     | 3 - muscovite   | 5 - quartz                  |
| 2 - K- feldspar | 4 - plagioclase | 6 - boundaries, holes, etc. |

# ranking filters: Median



- |                 |                 |                             |
|-----------------|-----------------|-----------------------------|
| 1 - biotite     | 3 - muscovite   | 5 - quartz                  |
| 2 - K- feldspar | 4 - plagioclase | 6 - boundaries, holes, etc. |

# Mean shift (image) - <http://rsb.info.nih.gov/ij/plugins/mean-shift.html>



1 - biotite

3 - muscovite

5 - quartz

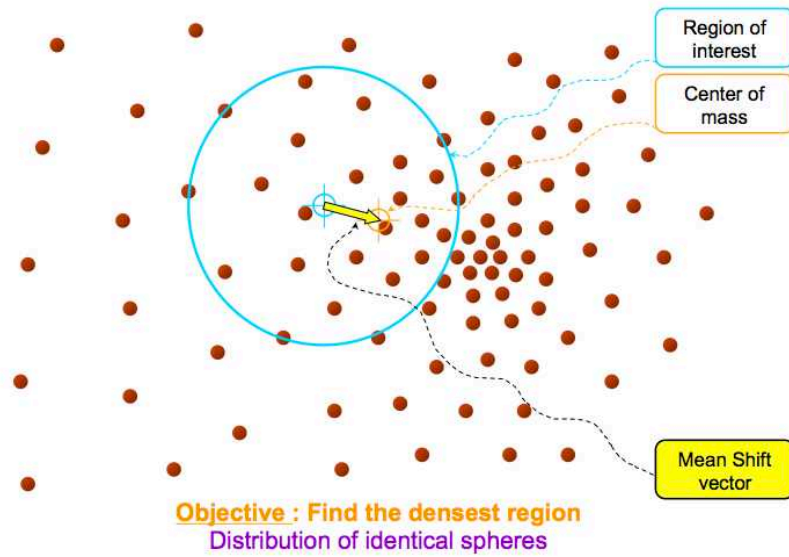
2 - K- feldspar

4 - plagioclase

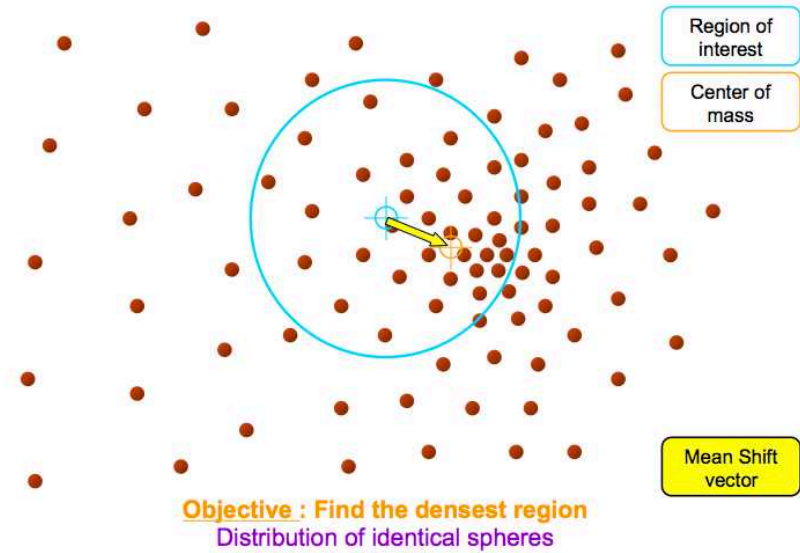
6 - boundaries, holes, etc.

# Mean shift (image) <http://rsb.info.nih.gov/ij/plugins/mean-shift.html>

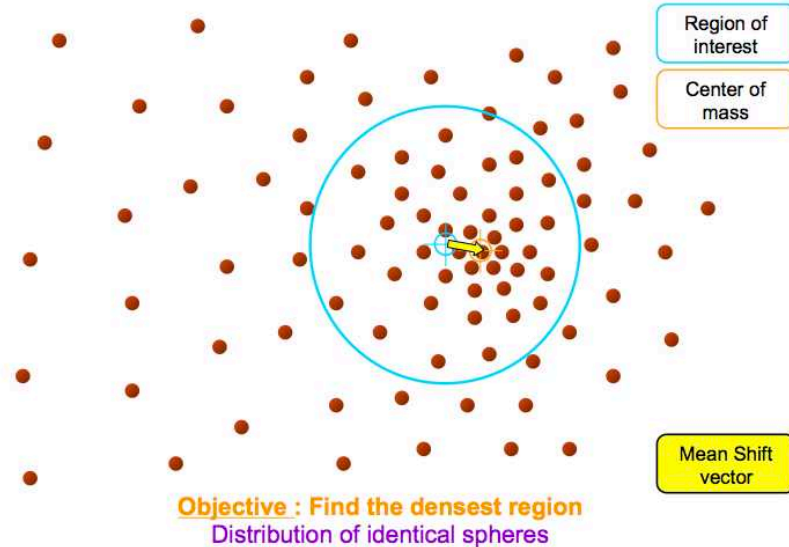
1



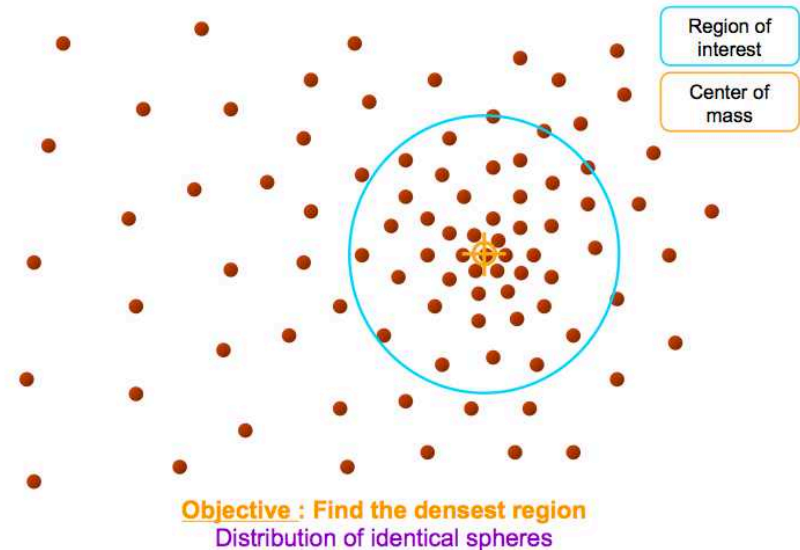
2



3



4



from [http://www.wisdom.weizmann.ac.il/~vision/courses/2004\\_2/](http://www.wisdom.weizmann.ac.il/~vision/courses/2004_2/)



# changing image size

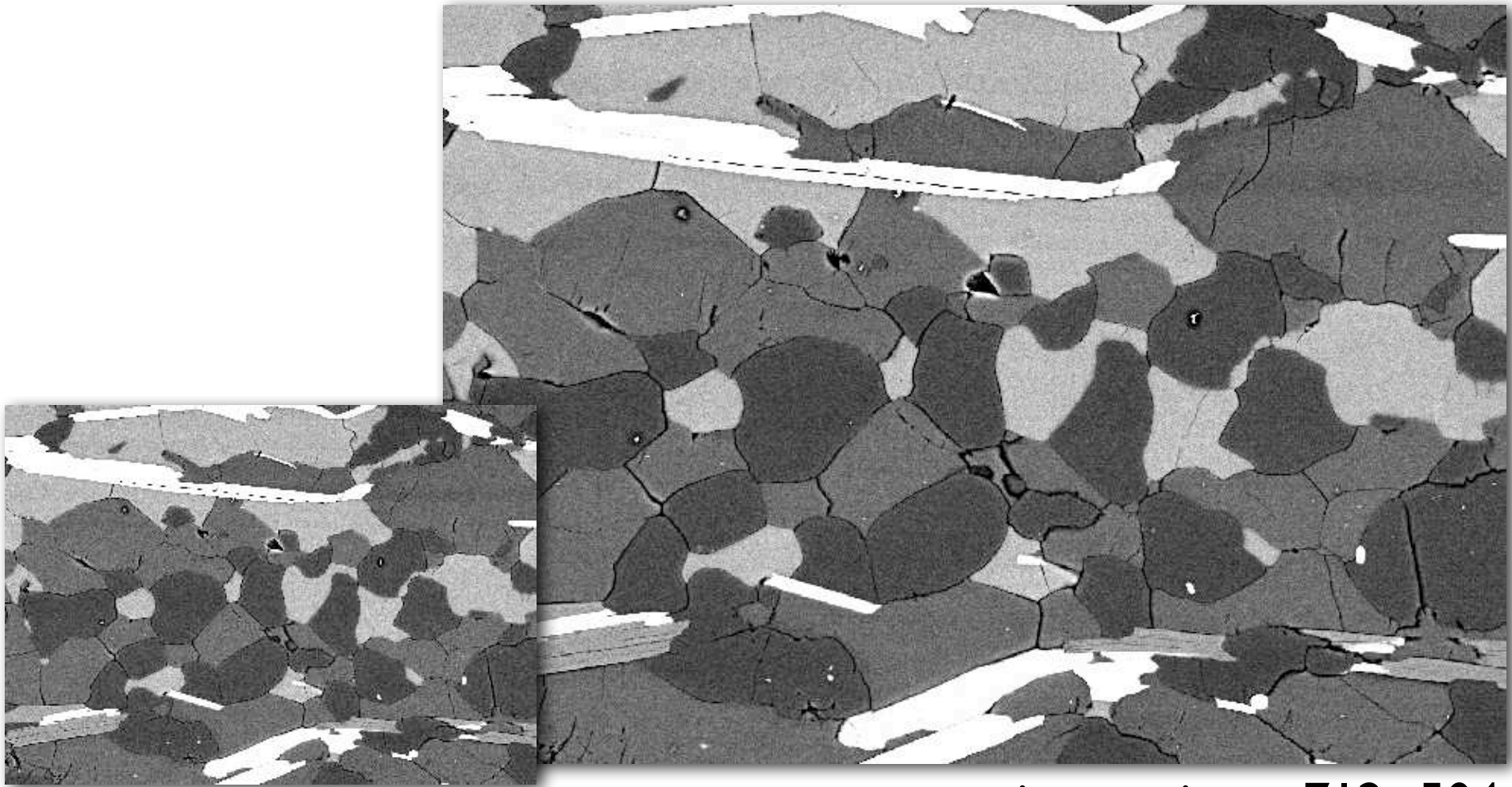
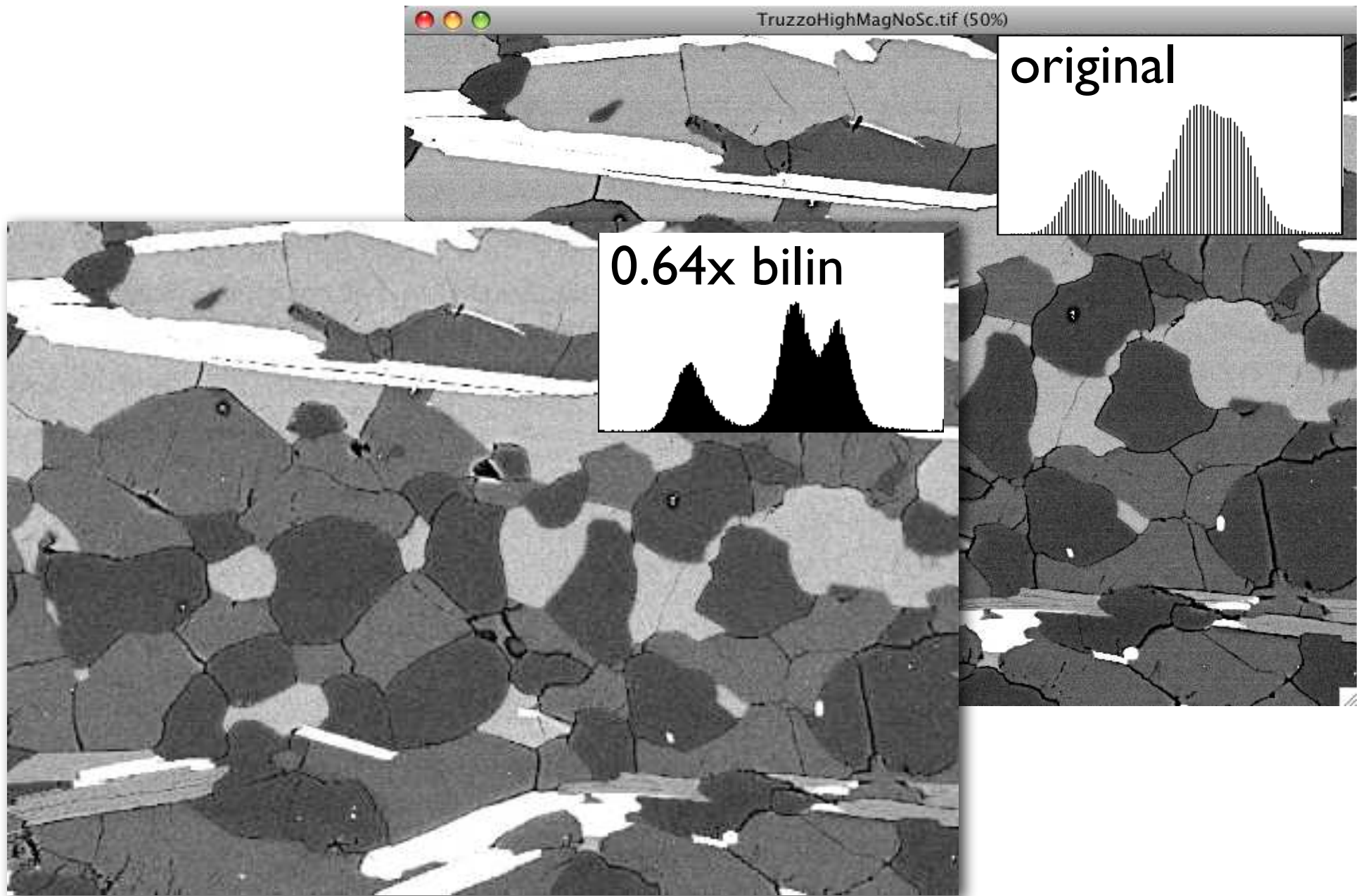


image size = 356 · 252  
1.03 px = 1 μm

image size = 712 · 504  
2.06 px = 1 μm

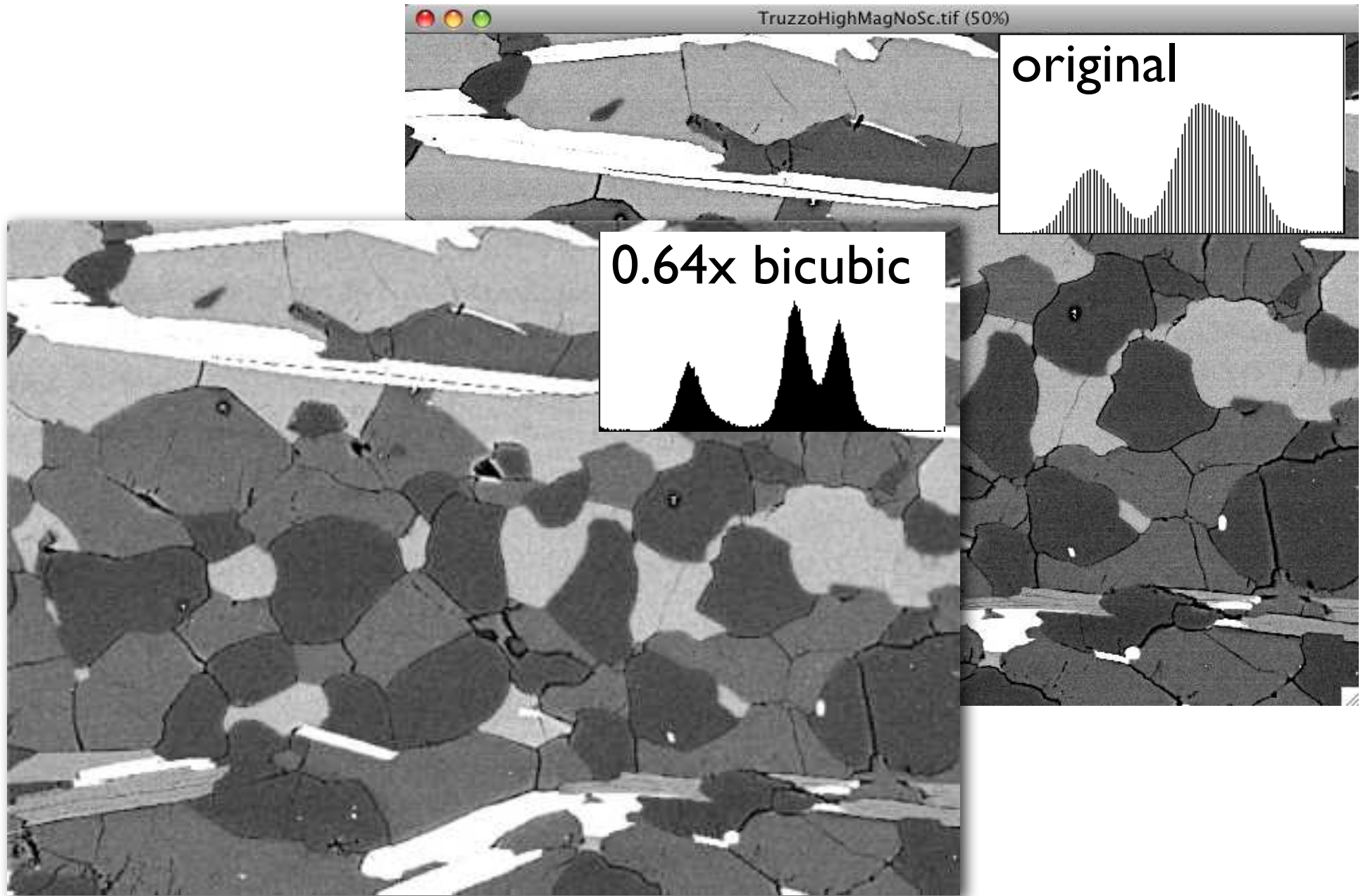
changing image size does affect scaling

# change of image size BILINEAR

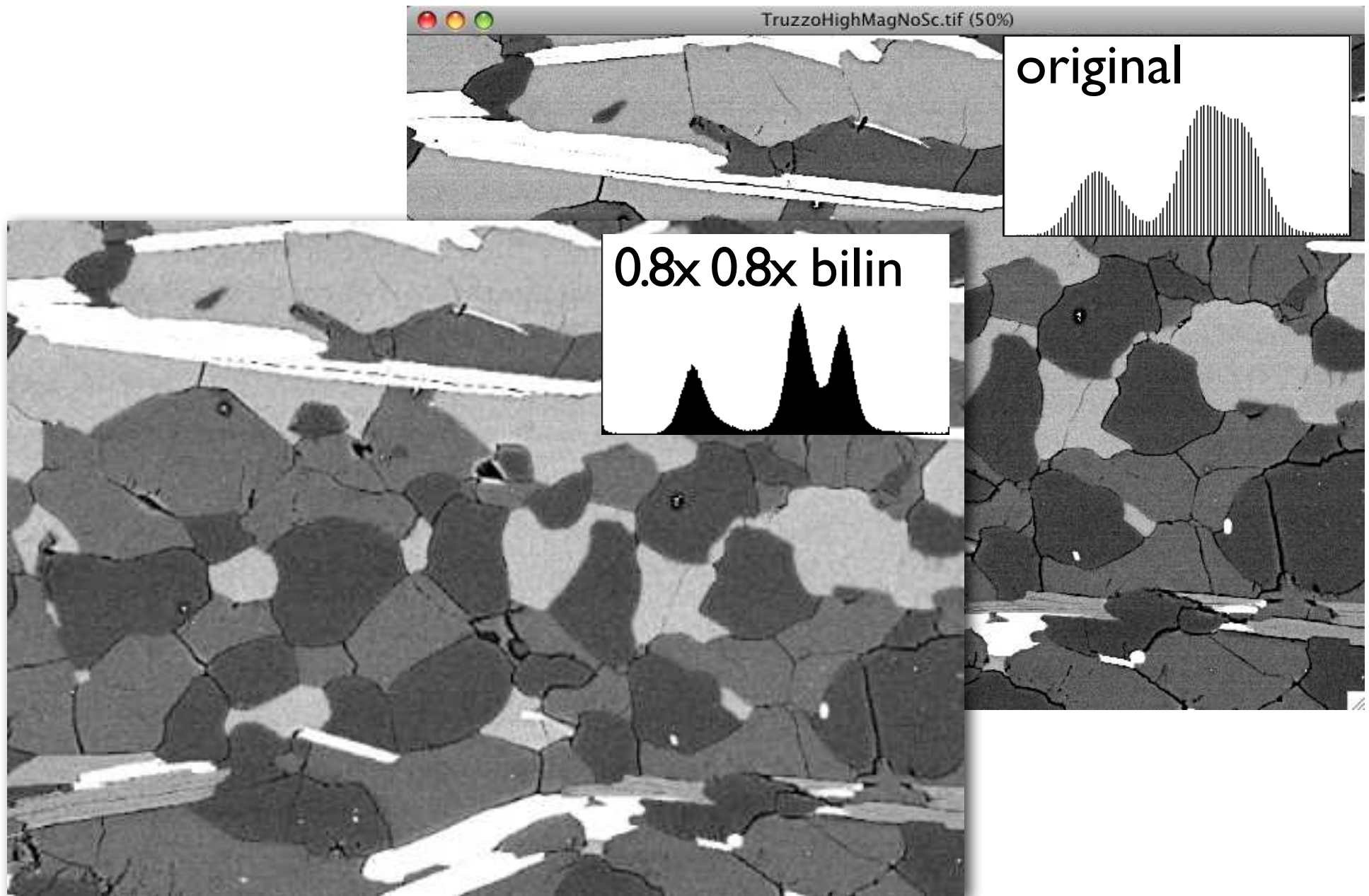




# change of image size BICUBIC



# progressive change of image size





# size change by 'equal temperament'

M = desired final magnification

s = number of steps

m = magnification at each step

$$m = \sqrt[s]{M}$$

$$m = \sqrt[2]{0.5} = 2 \text{ times } 0.707$$

$$m = \sqrt[5]{4} = 5 \text{ times } 1.3195$$



Johann Sebastian Bach

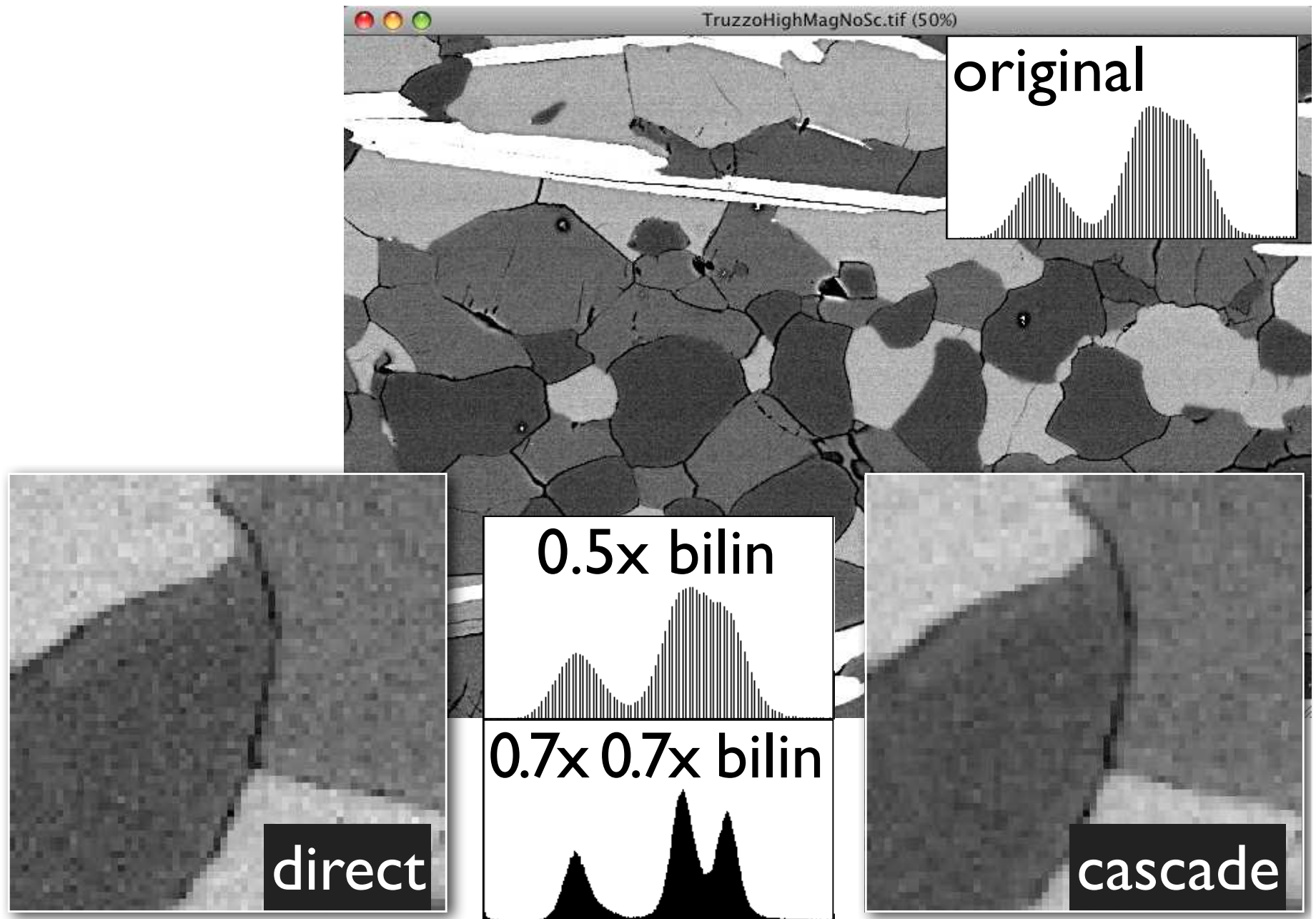
'Das wohltemperierte Klavier'

(wikipedia)

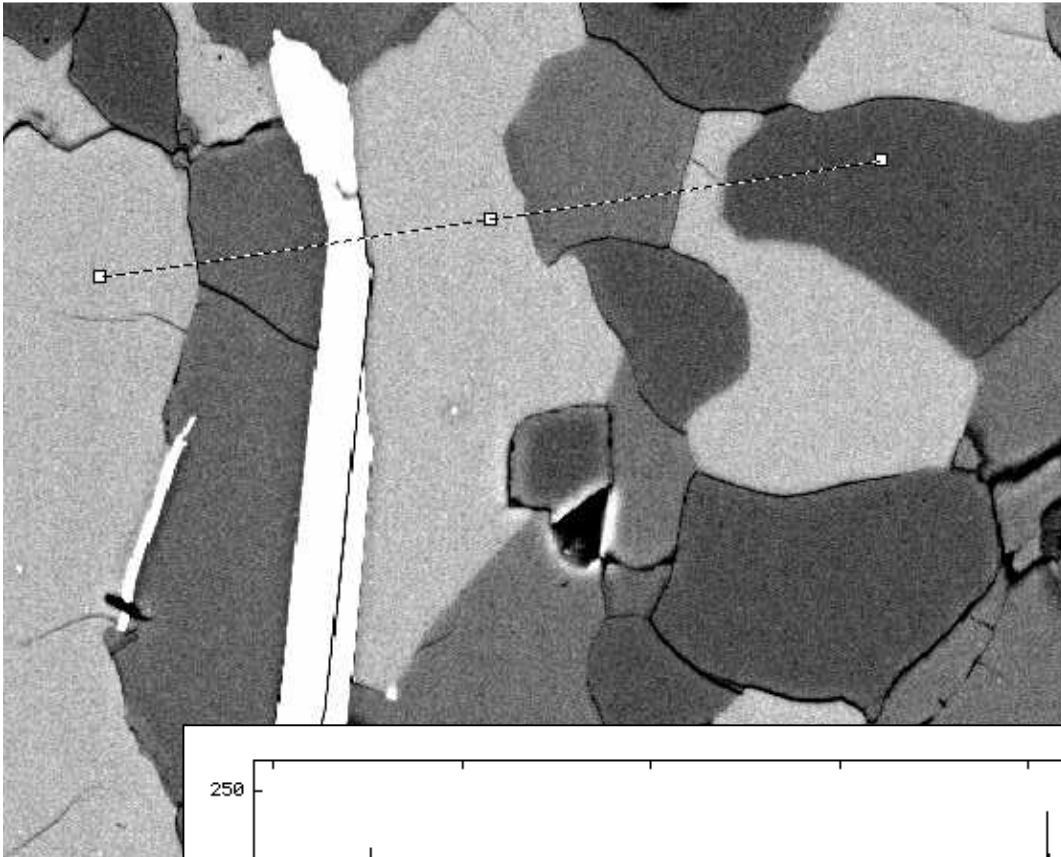
chromatic scale: halftone 'magnification'  
 $\sqrt[12]{2} = 1.05946$  (12 halftones/octave)

61	a''	A5	880.000
60	g#''/ab''	G#5/Ab5	830.609
59	g''	G5	783.991
58	f#''/gb''	F#5/Gb5	739.989
57	f''	F5	698.456
56	e''	E5	659.255
55	d#''/eb''	D#5/Eb5	622.254
54	d''	D5	587.330
53	c#''/db''	C#5/Db5	554.365
52	c'' 2-line octave	C5 Tenor C	523.251
51	b'	B4	493.883
50	a#'/bb'	A#4/Bb4	466.164
49	a'	A4 A440	440.000

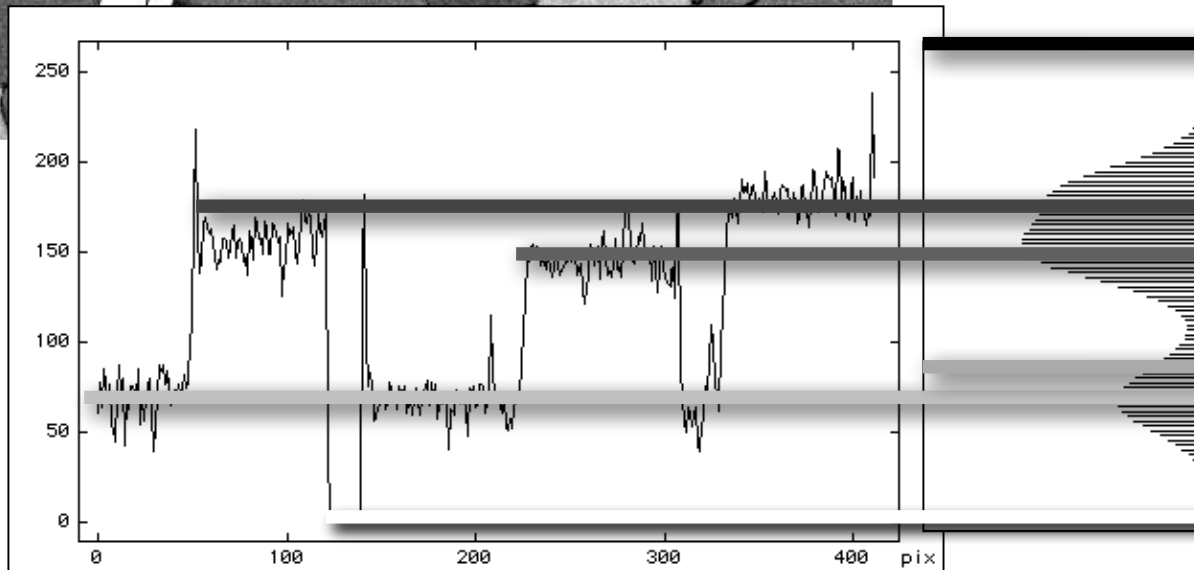
# progressive change of image size



# Profiles



original



6 - holes etc.

5 - quartz

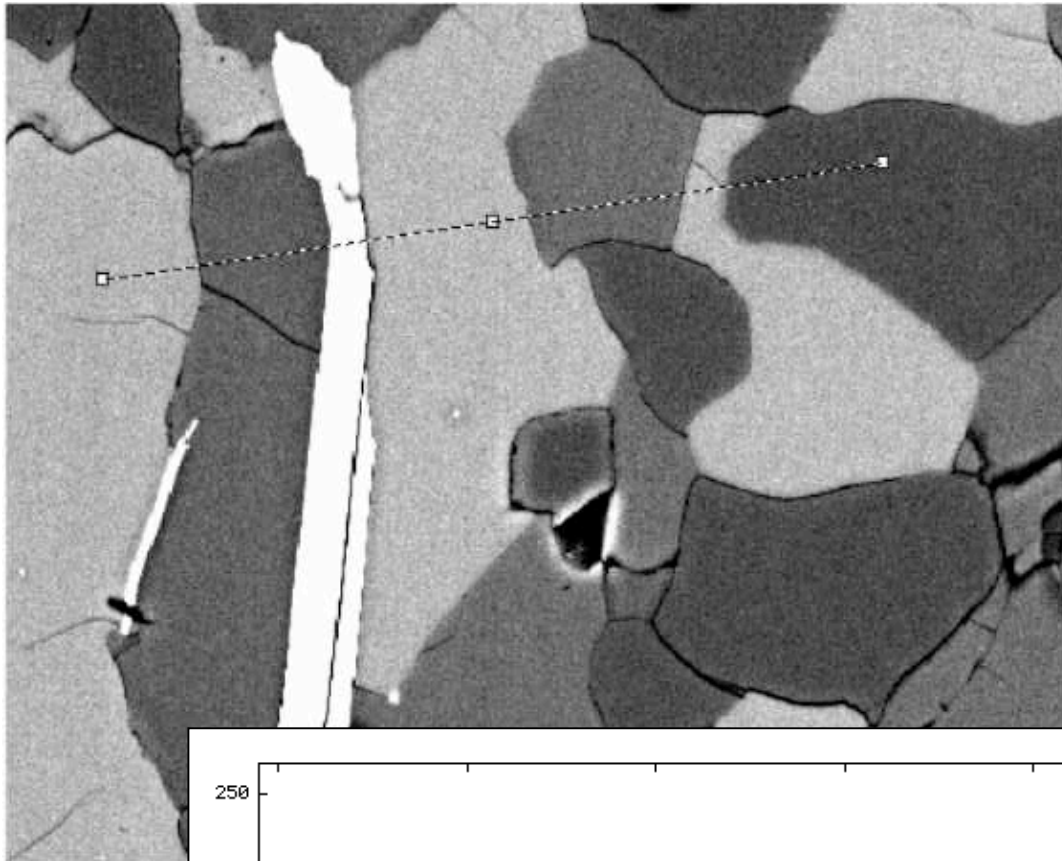
4 - plagioclase

3 - muscovite

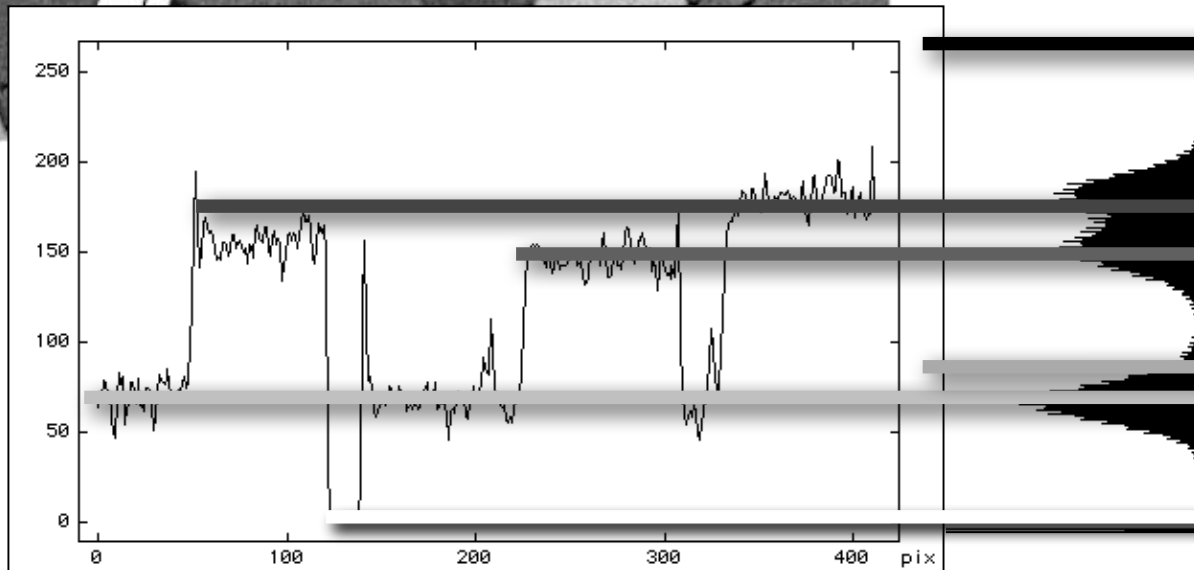
2 - K- feldspar

1 - biotite

# Profiles



x 1.25 bilin  
x 0.80 bilin



6 - holes etc.

5 - quartz

4 - plagioclase

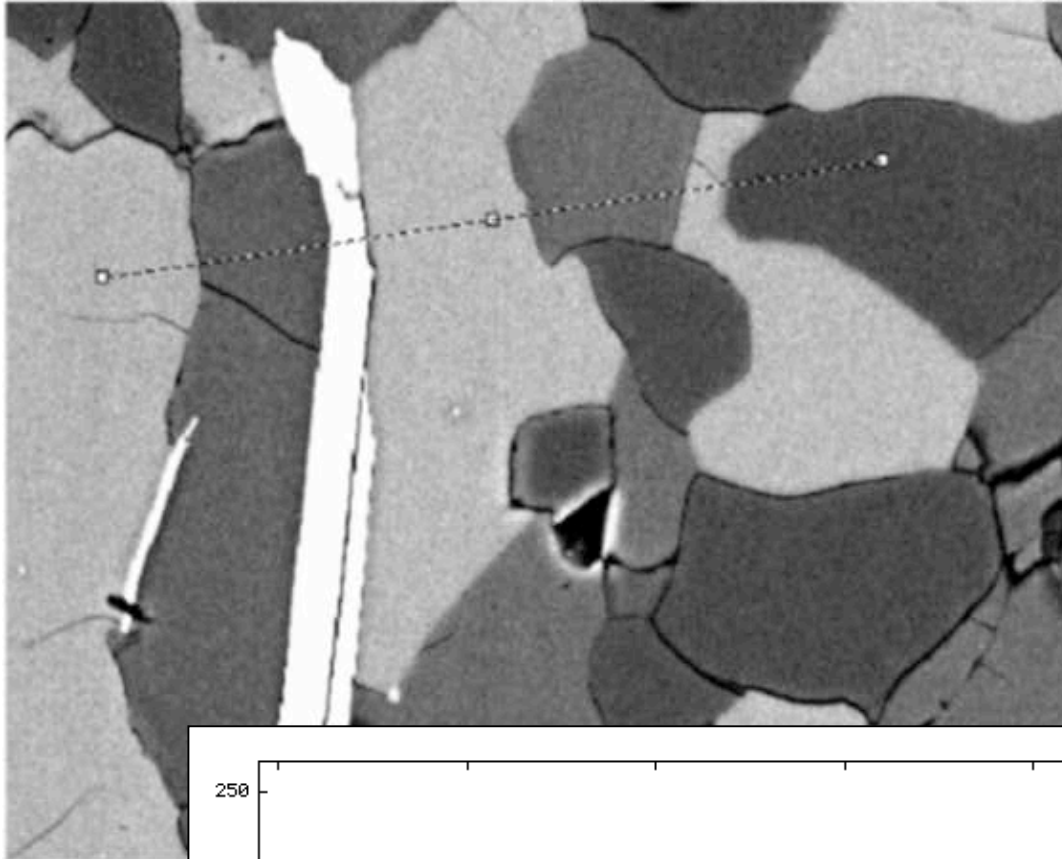
3 - muscovite

2 - K- feldspar

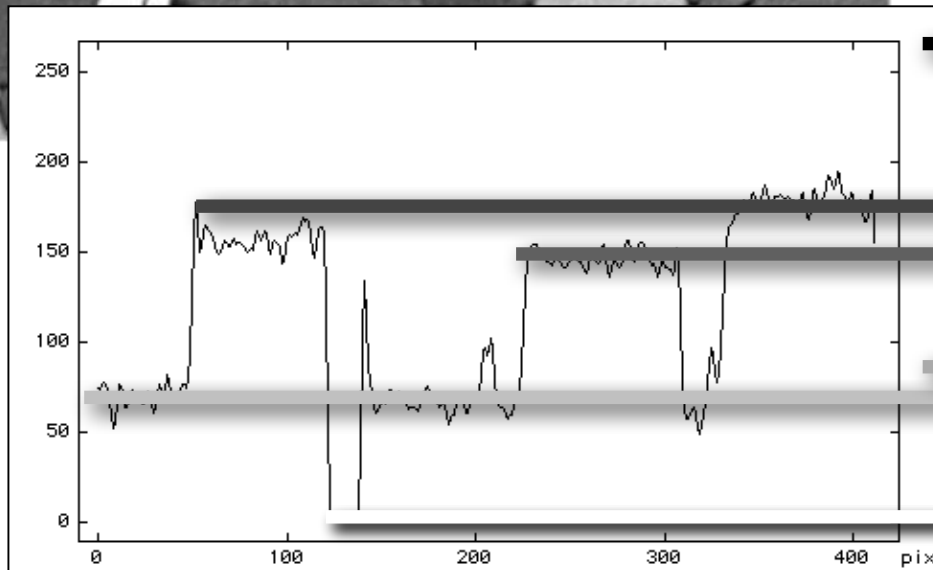
1 - biotite



# Profiles



x 1.25 bilin  
x 0.80 bilin  
smoothed



6 - holes etc.

5 - quartz

4 - plagioclase

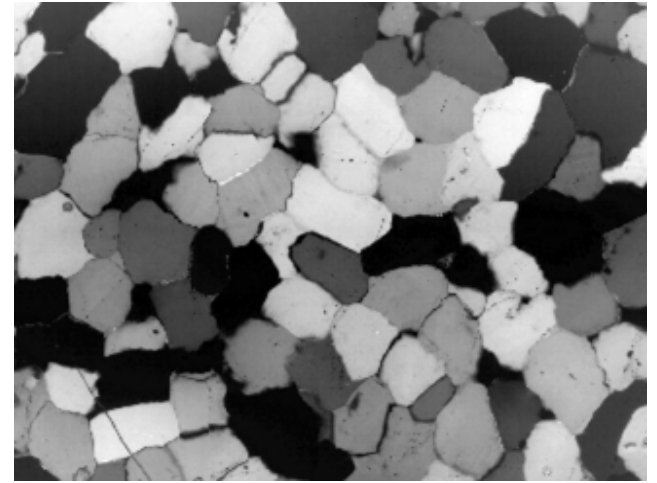
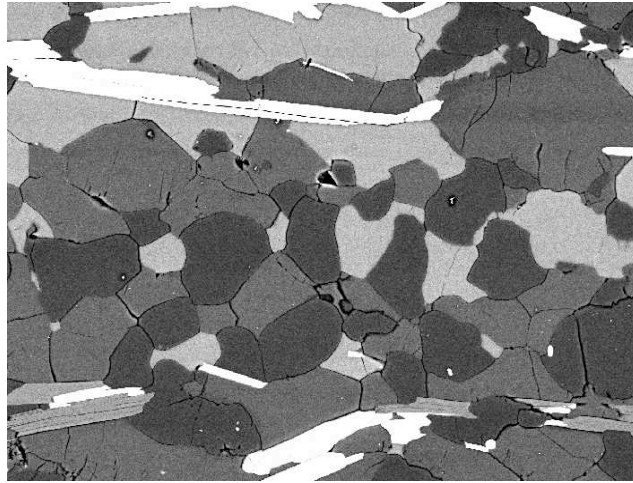
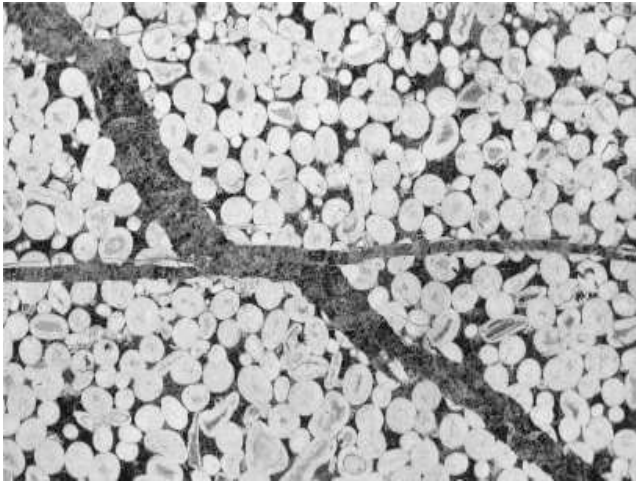
3 - muscovite

2 - K- feldspar

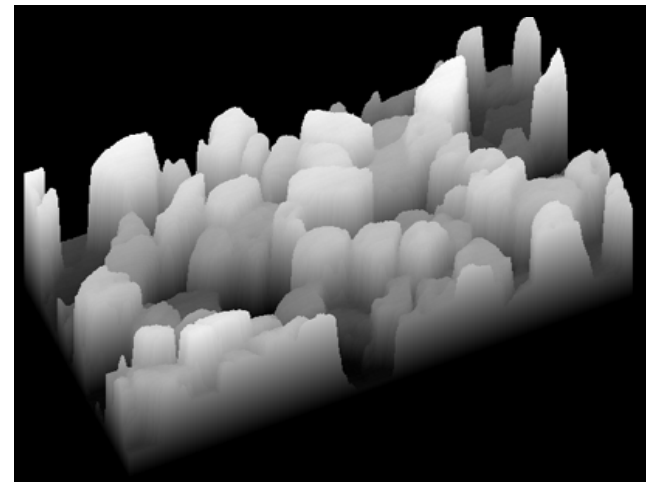
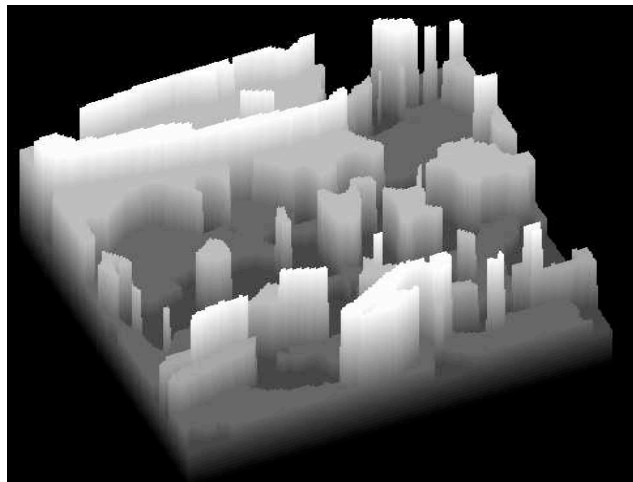
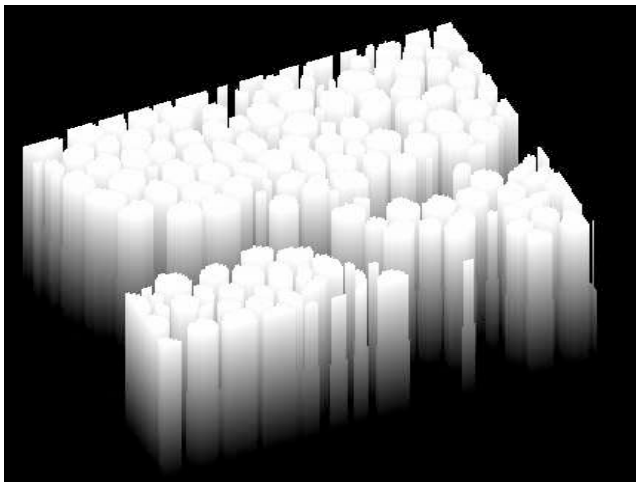
1 - biotite

# image models for segmentation

# Image models

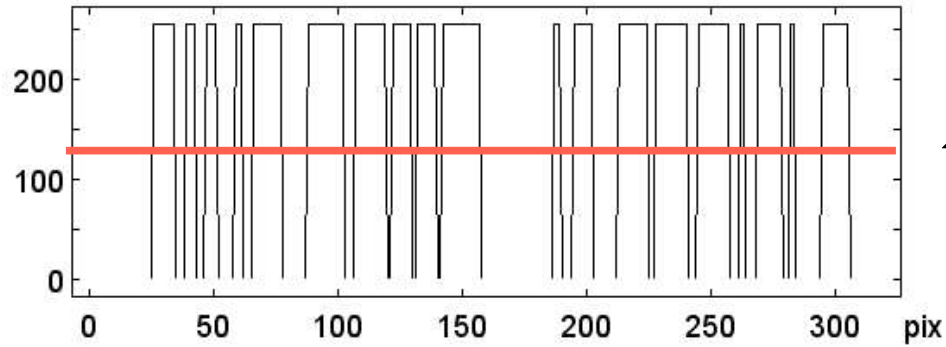
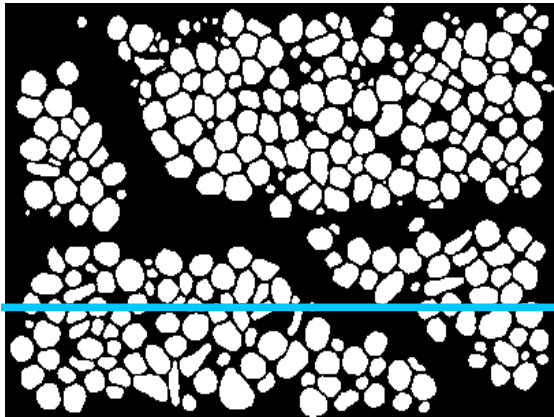


images

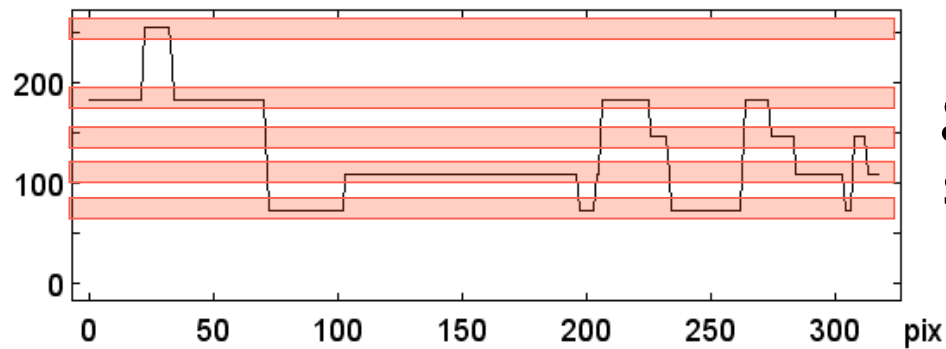
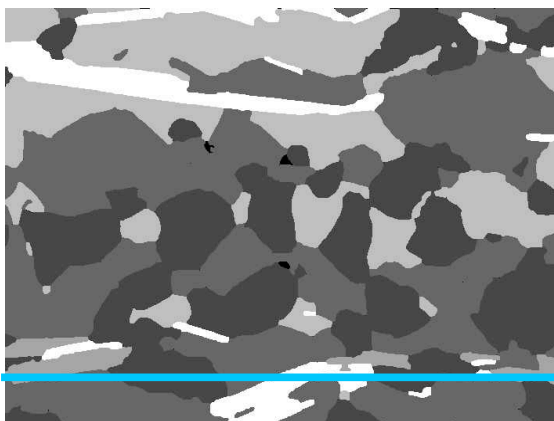


models

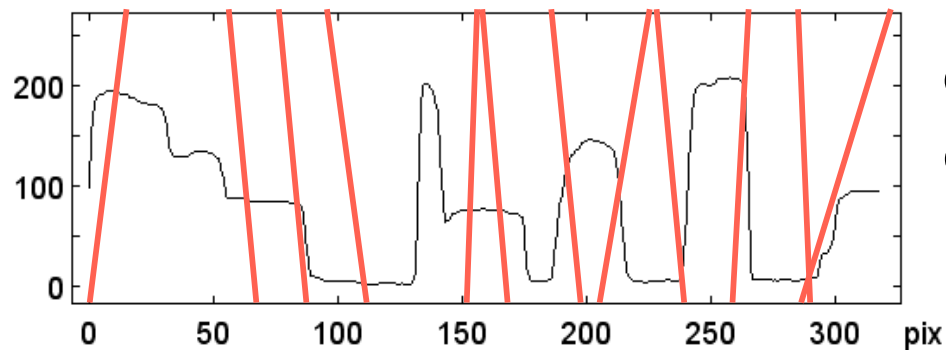
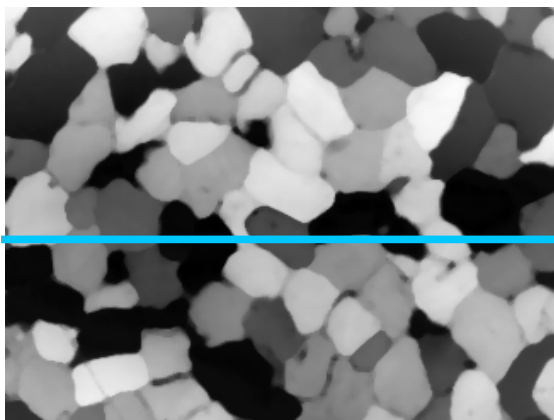
# Segmentation based on image model



thresholding



grey level  
slicing

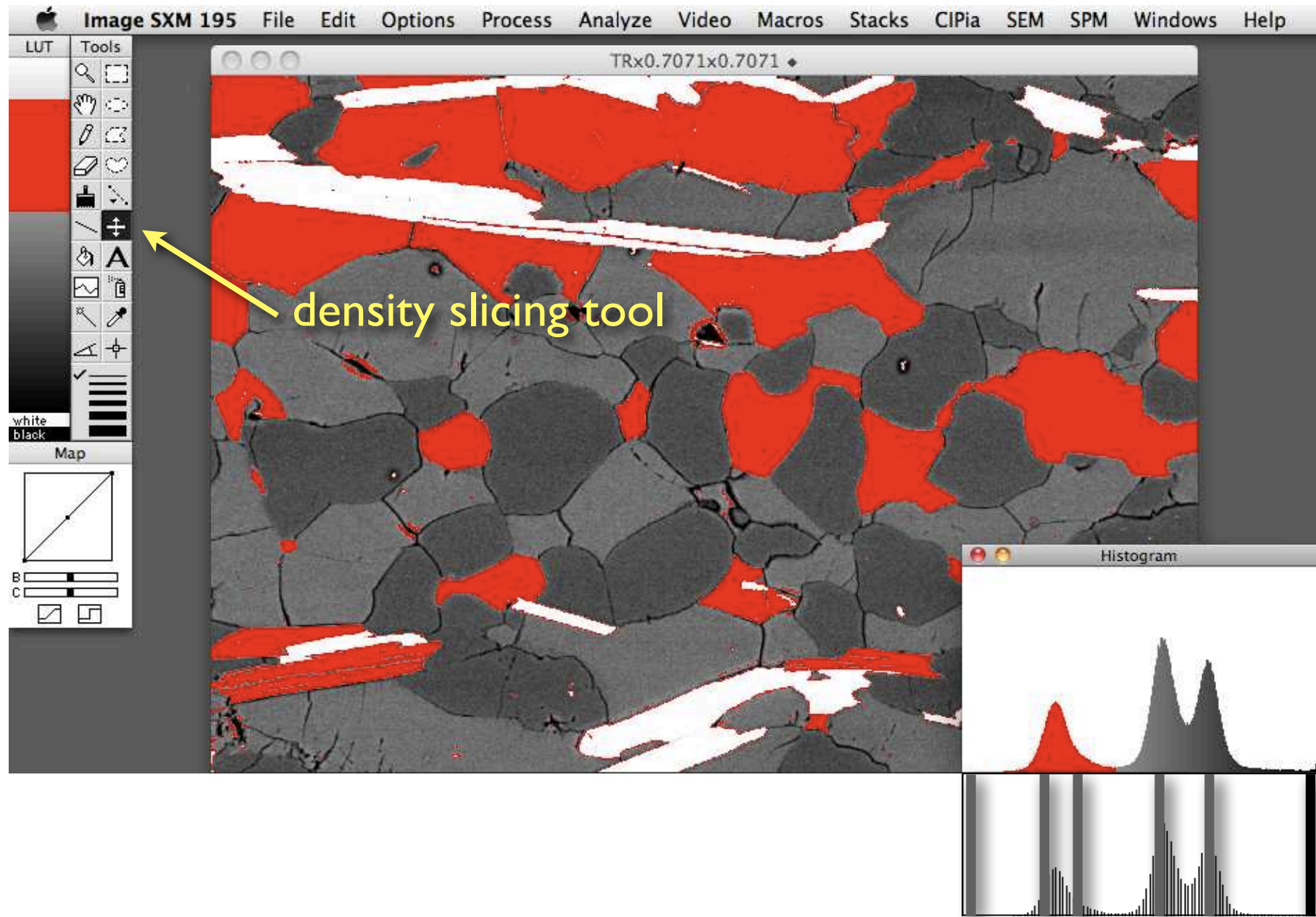


edge  
detection

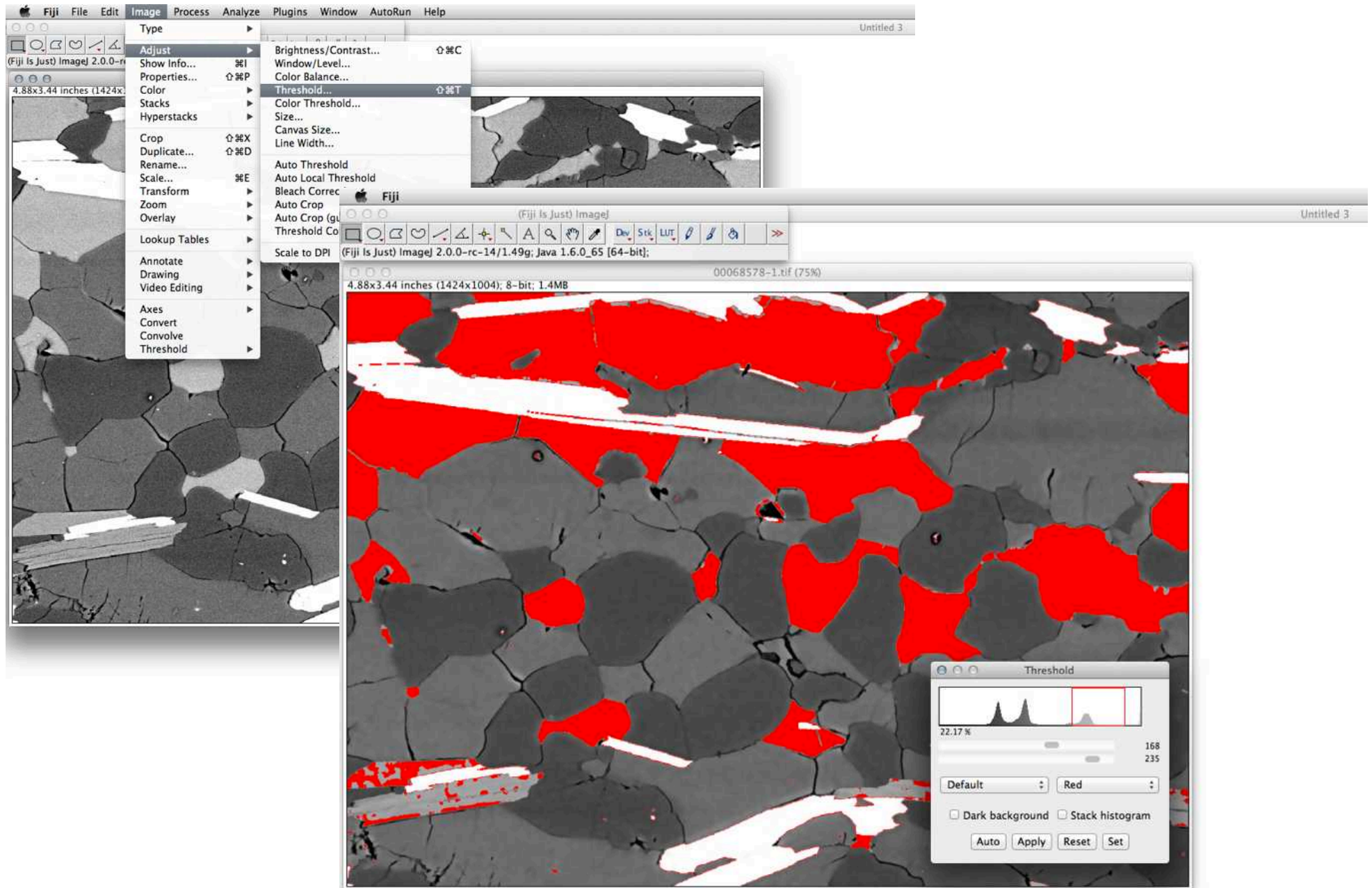


grey level slicing  
live segmentation

# Density Slicing

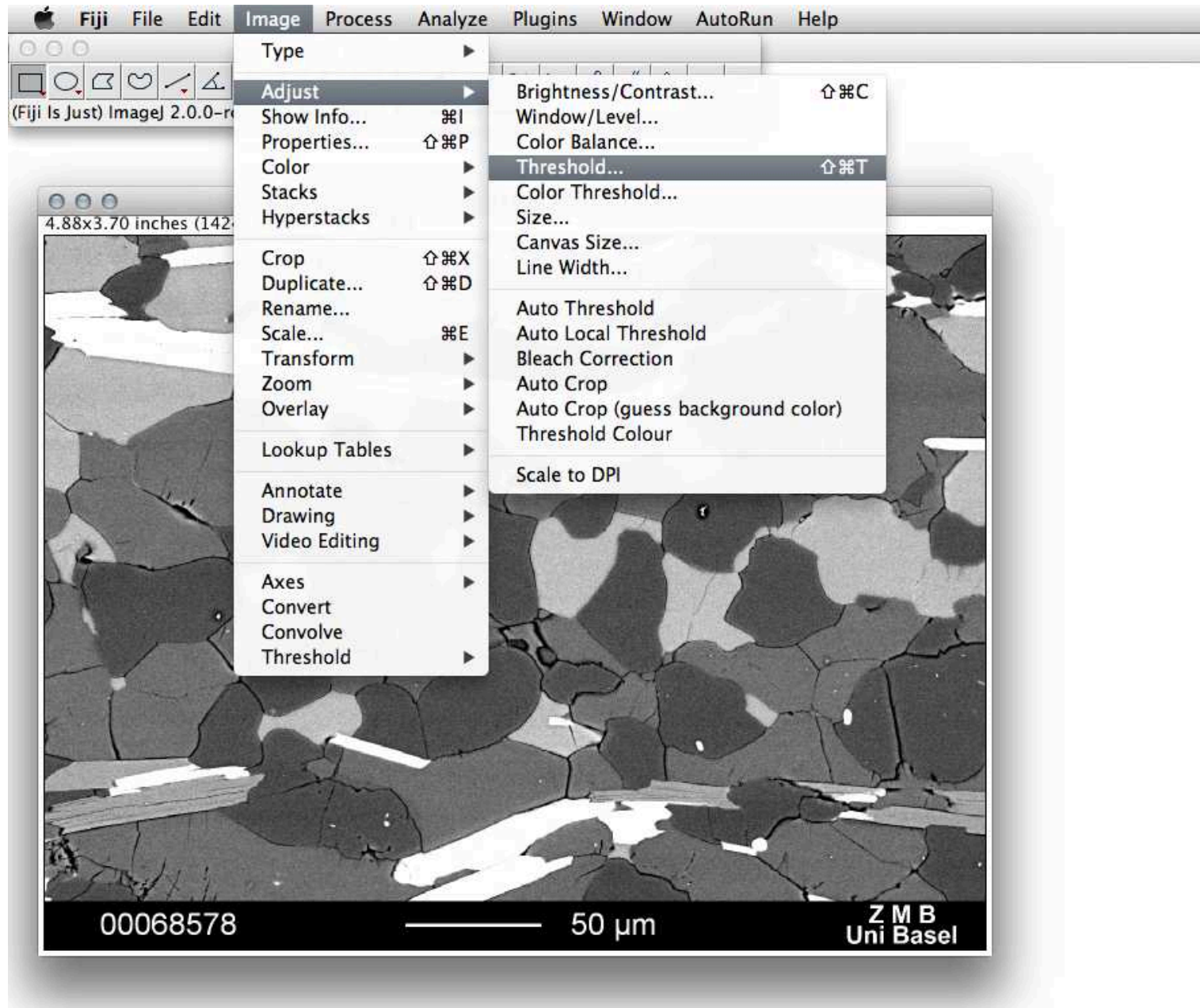


# Density Slicing = Threshold in imagej



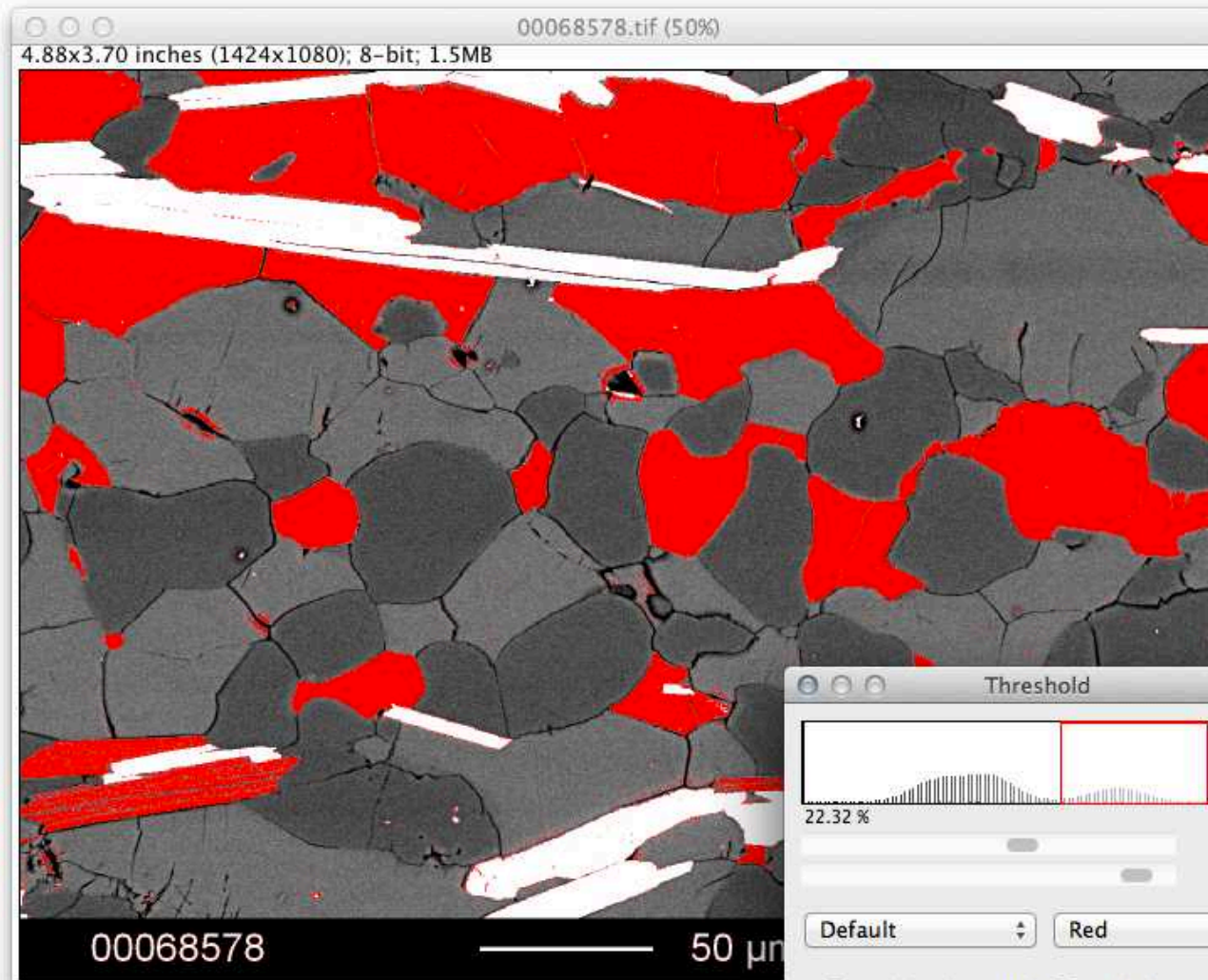


# Density Slicing/Threshold in imagej

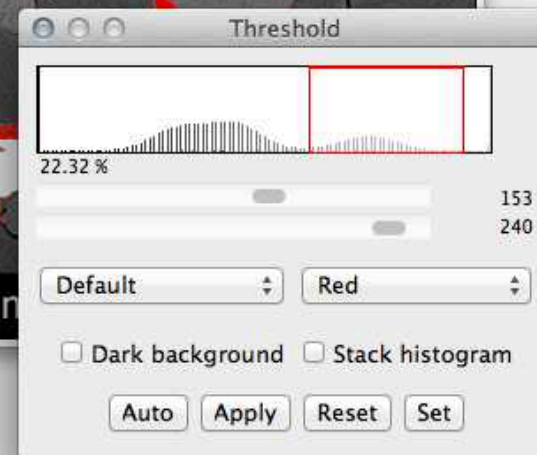




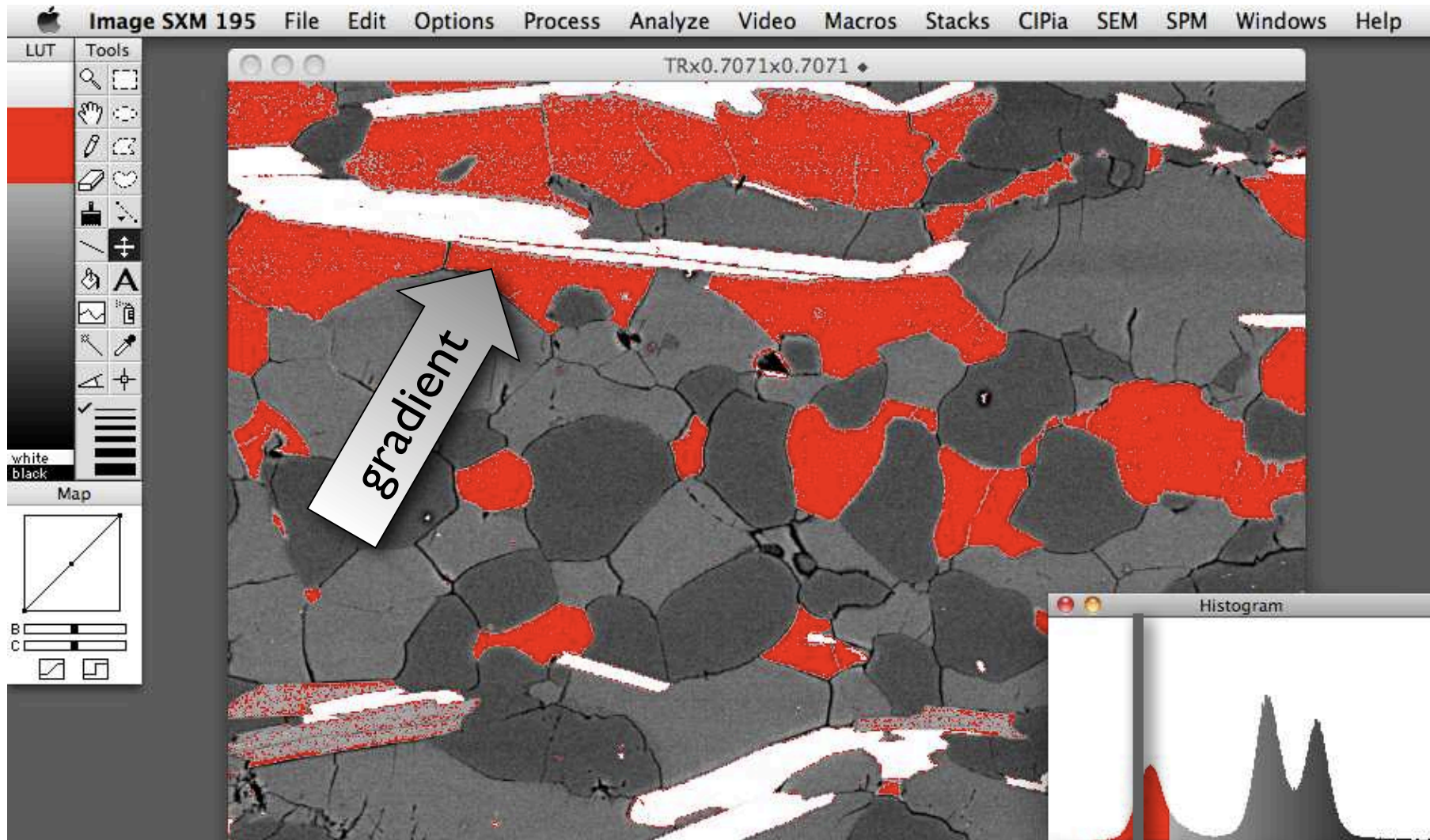
# Density Slicing/Threshold in imagej



0 und 255  
können  
ausgewählt  
werden



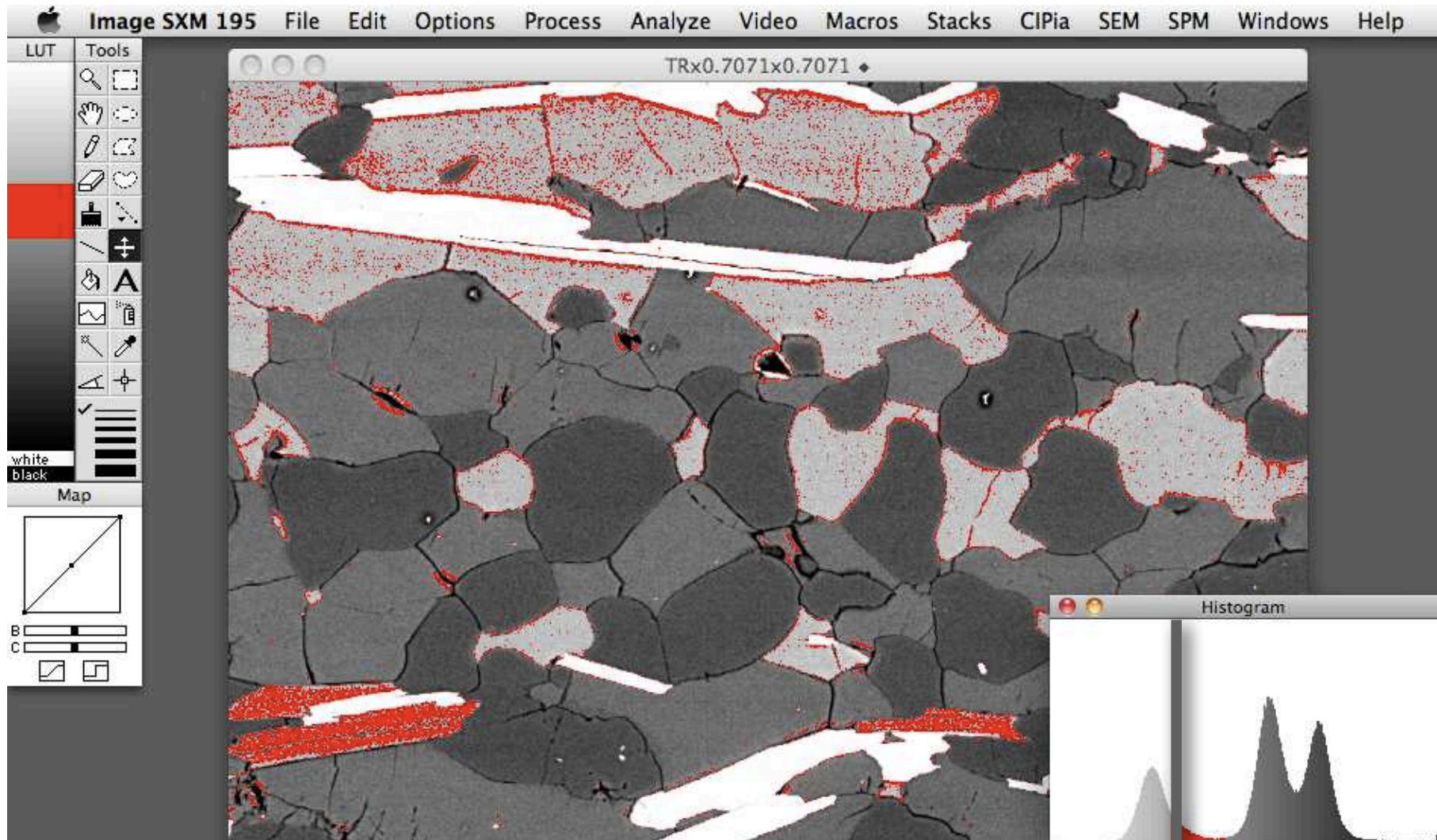
# Density Slicing



2 - K- feldspar

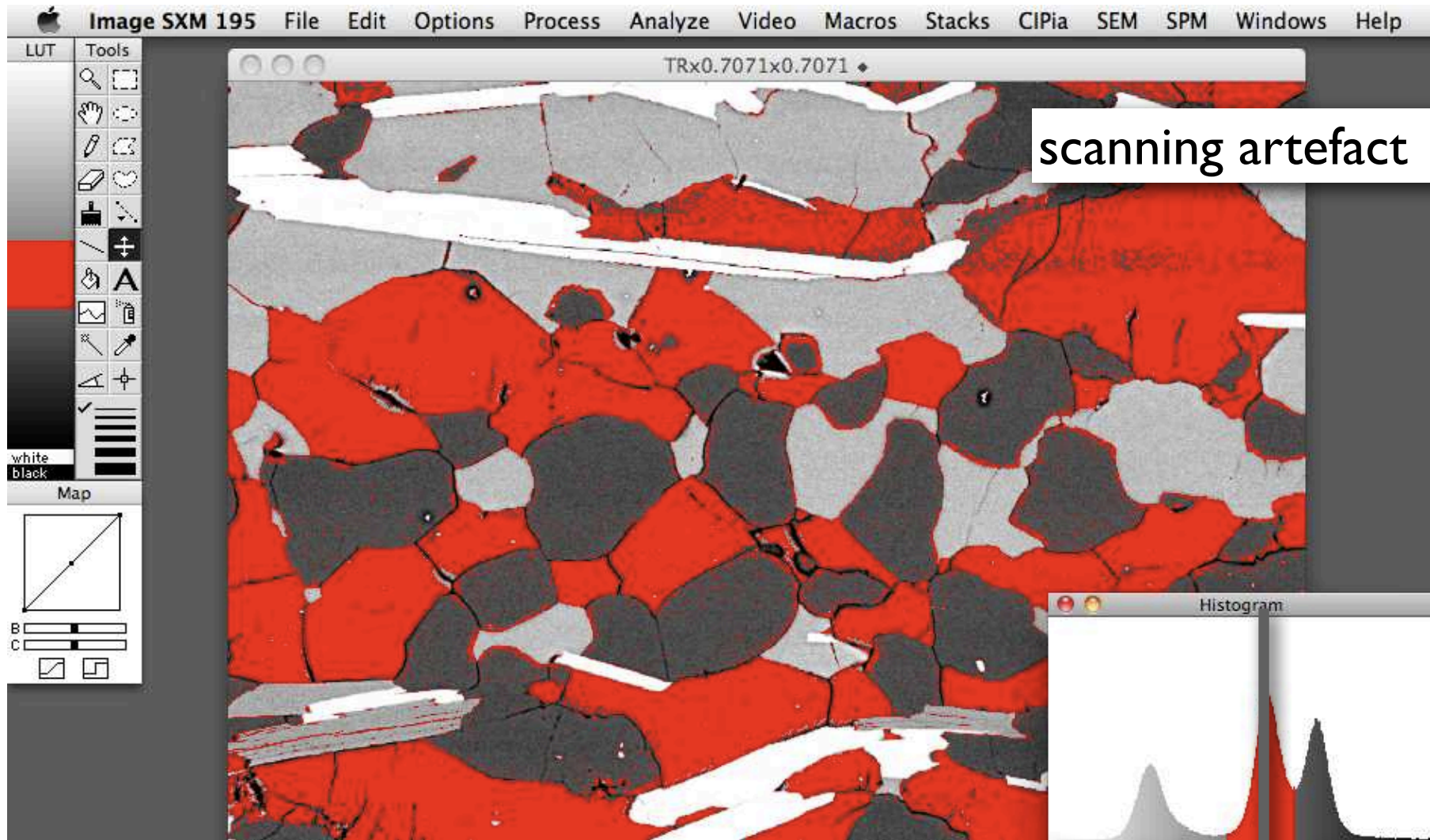


# Density Slicing



3 - muscovite

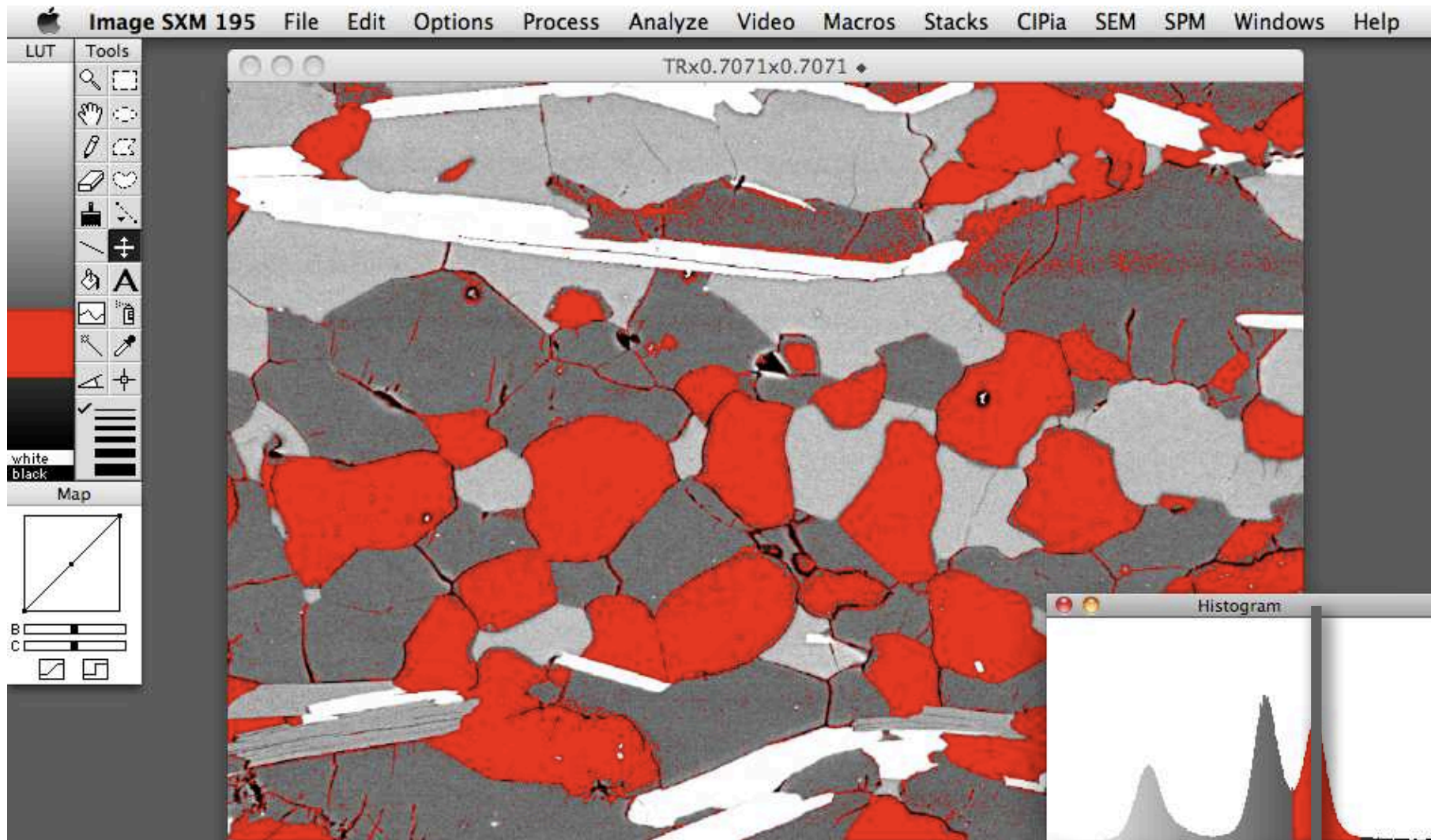
# Density Slicing



4 - plagioclase

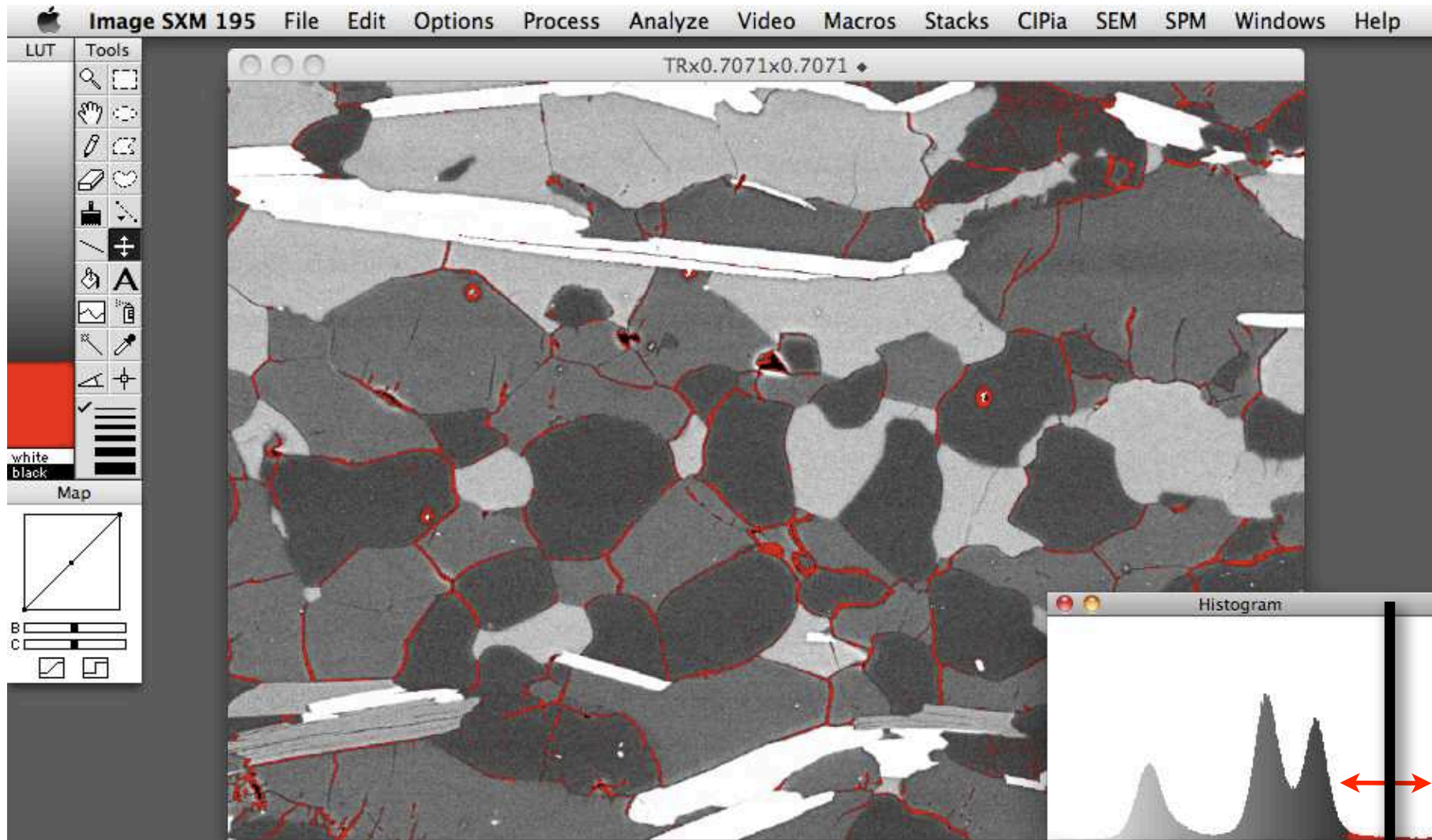


# Density Slicing



5 - quartz

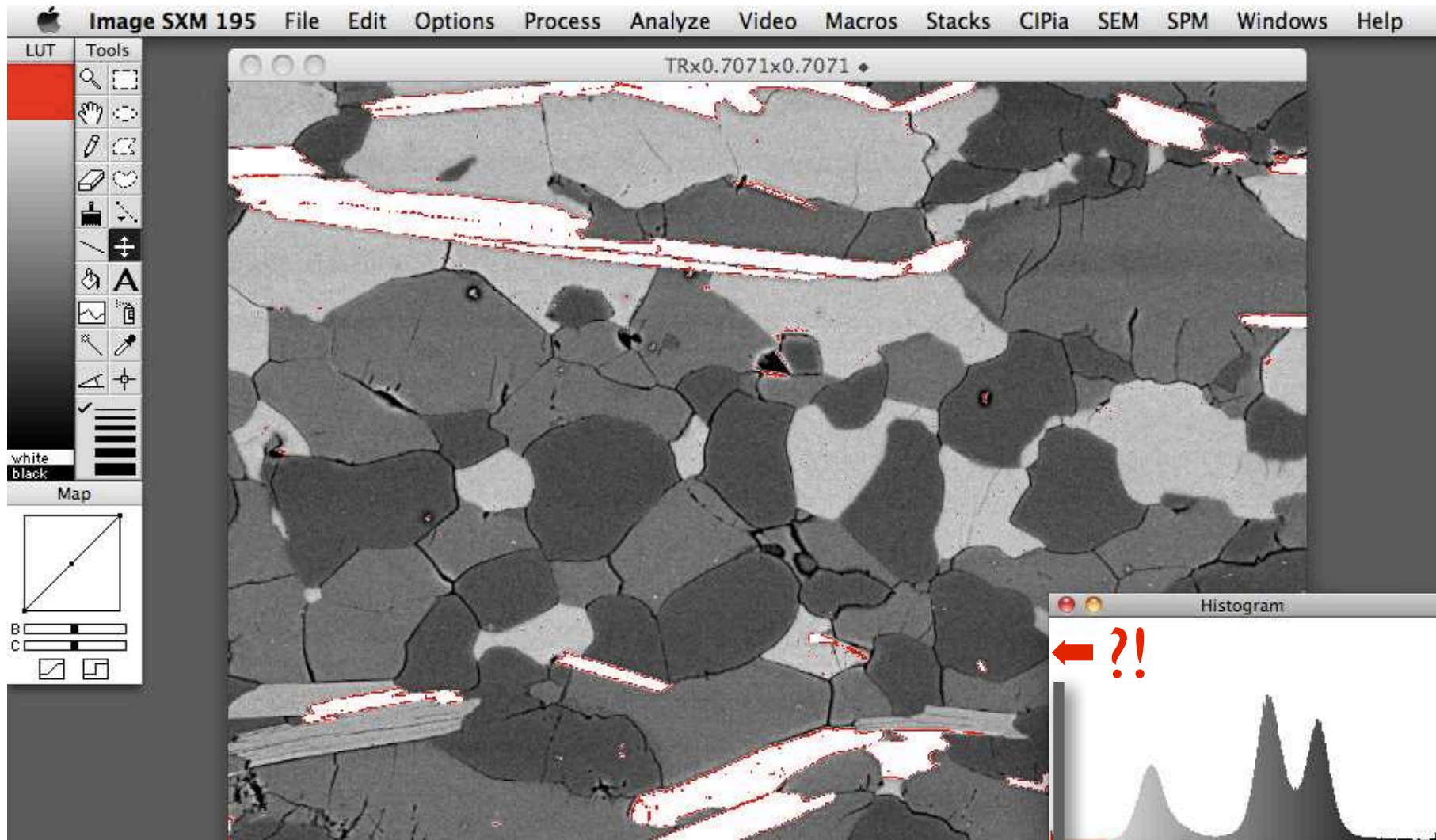
# Density Slicing



boundaries,  
holes, etc.

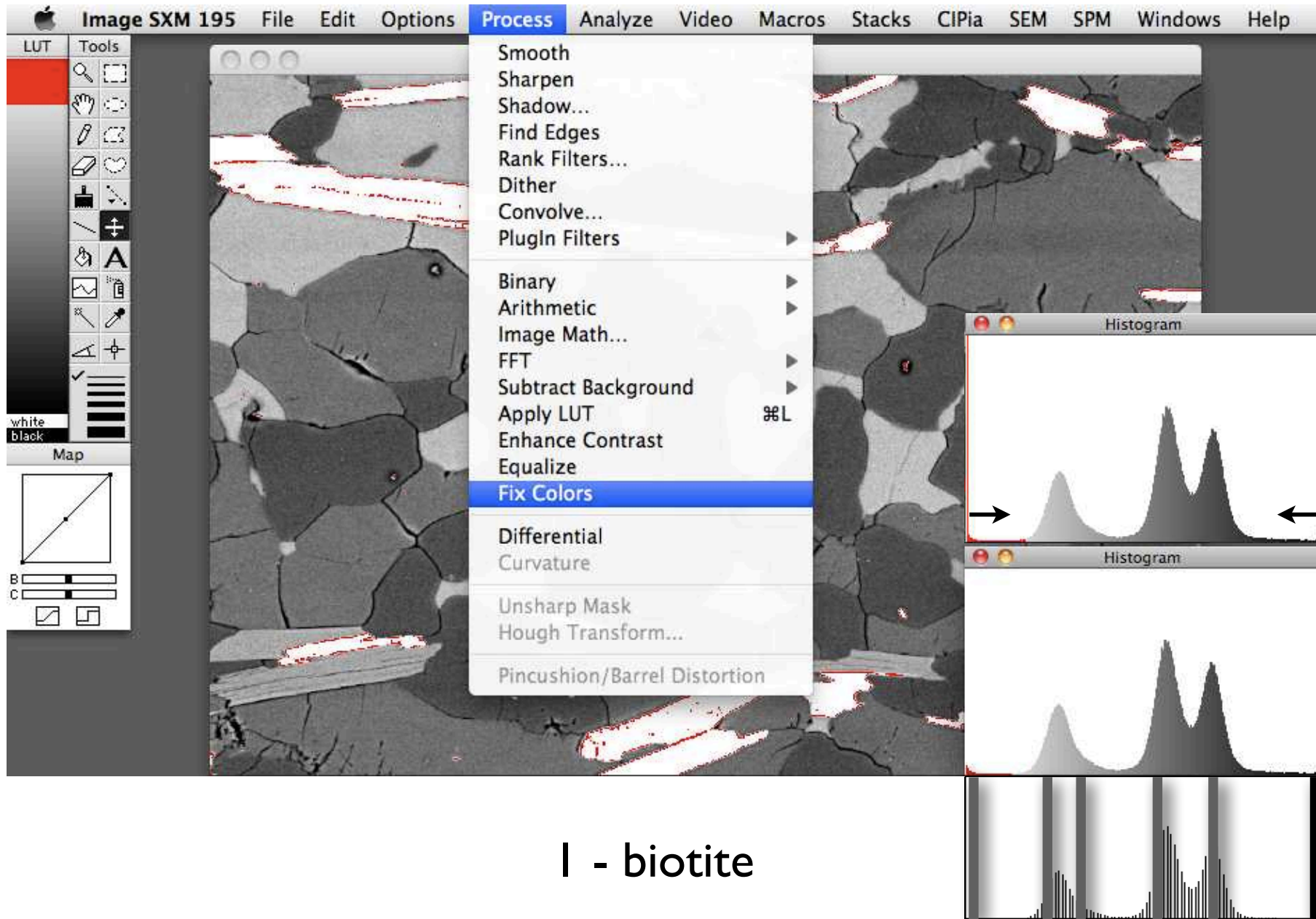


# Density Slicing



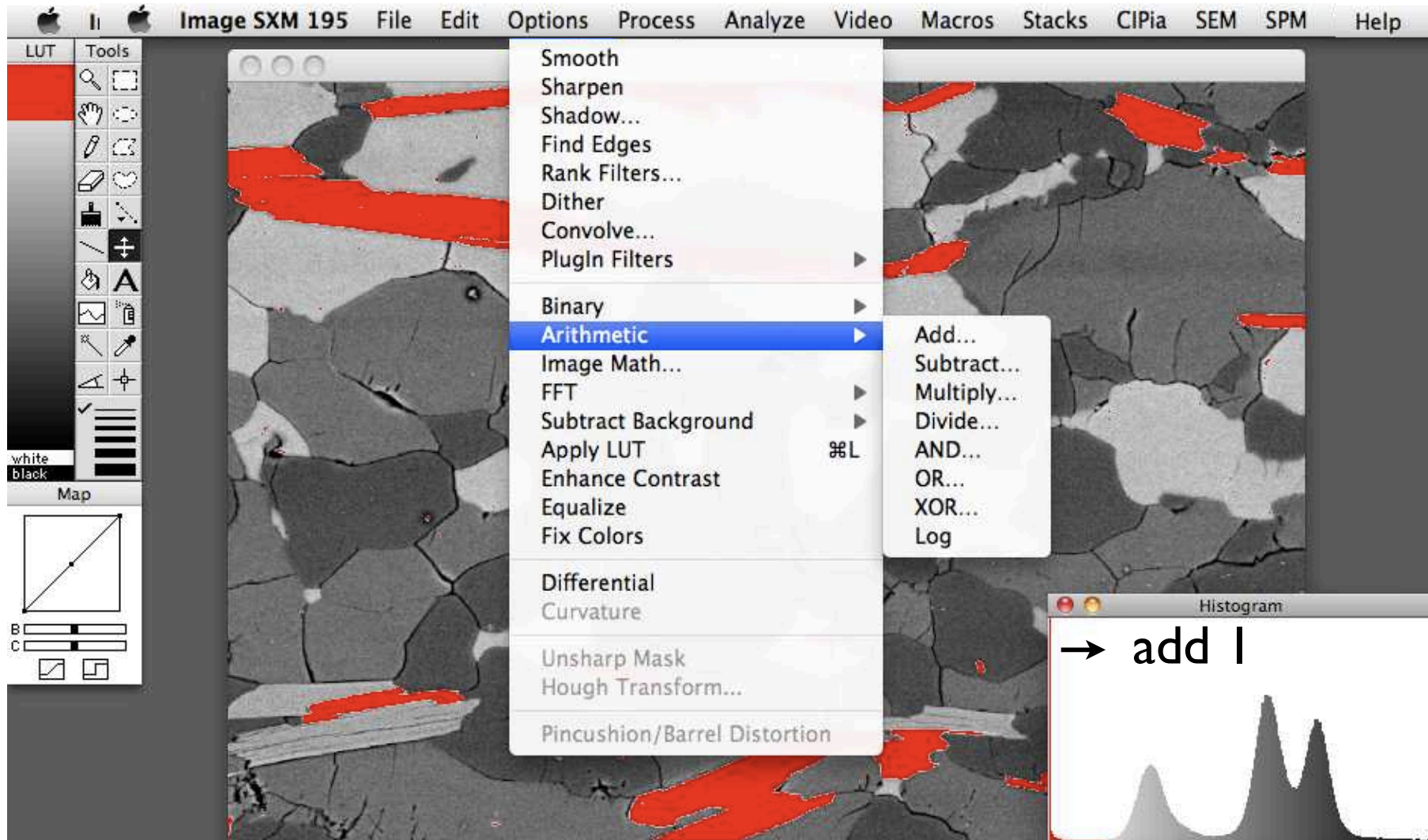
I - biotite

# Density Slicing

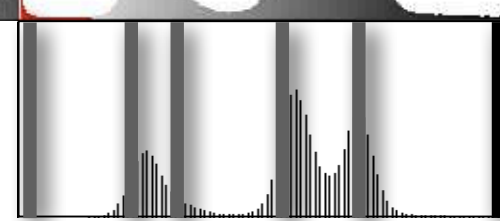




# Density Slicing



I - biotite



# Übung 9 - Pre-processing

Bilder für die Segmentierung vorbereiten.

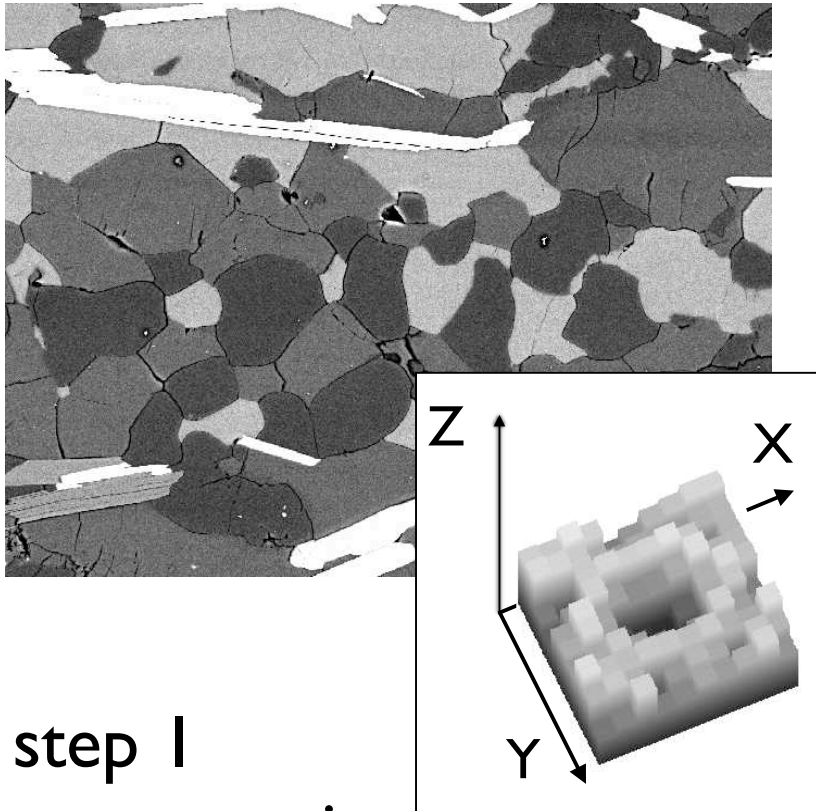
- Öffnen Sie die Bilder 00068574.tif, 00068578.tif und 00068557.tif im Ordner Truzzo.

Führen Sie an einem dieser Bilder ein “pre-processing” durch:  
crop, noise reduction, histogram conditioning.  
Vergleichen Sie die verschiedenen Verfahren.

Führen Sie eine, auf den Grauwerten basierende Segmentierung durch und erzeugen sie einen Stack mit einem slice für jede Phase (qtz, kfs, plg, ms, bt, Löcher/Staub/Korngrenzen = maximal 6 slices).  
Speichern Sie den resultierenden Stack, Sie werden ihn noch benötigen.

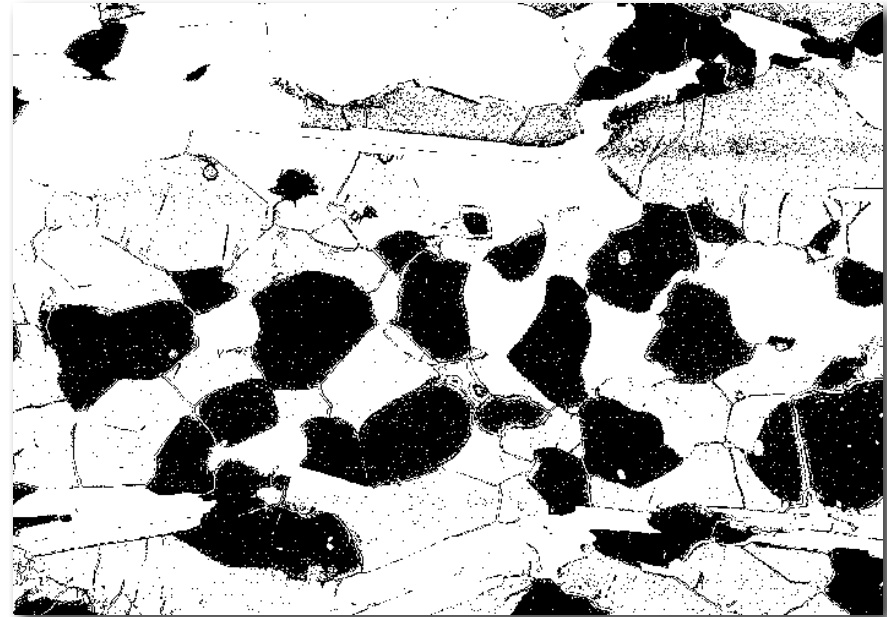
post-processing  
ranking filters  
structural  
filtering

# segmentation: point operation



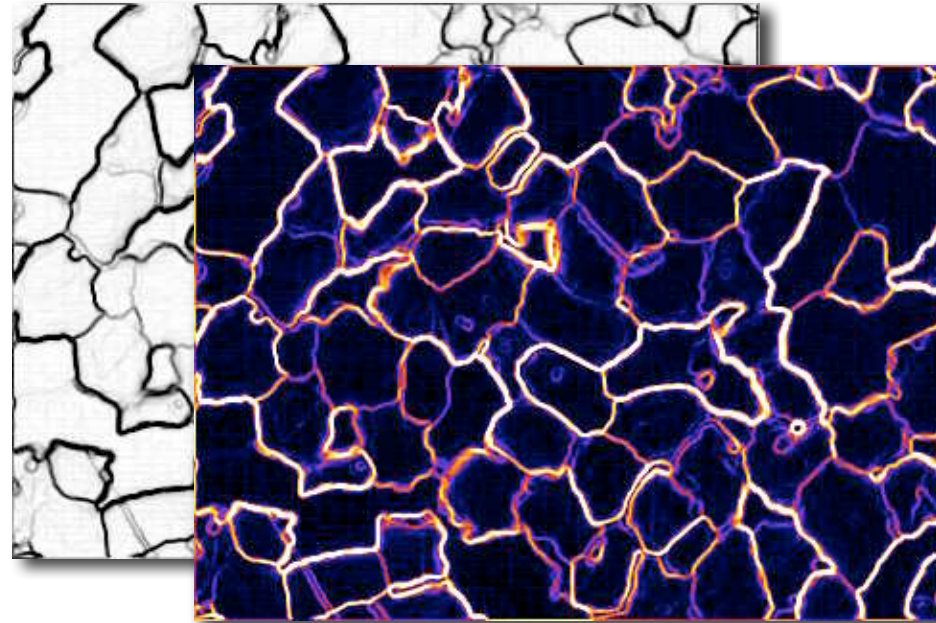
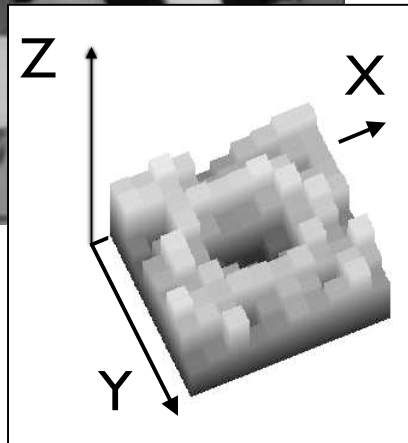
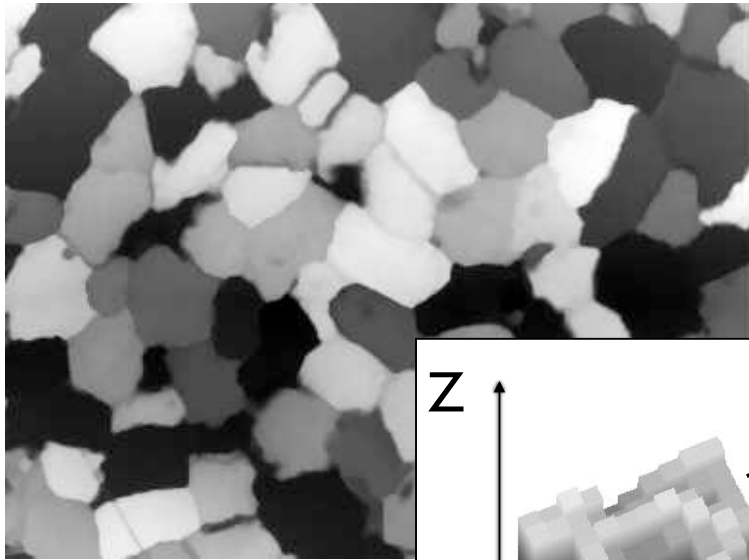
step 1  
segmentation  
basis = grey value (Z)  
⇒ bitmap

step 2  
structural filtering



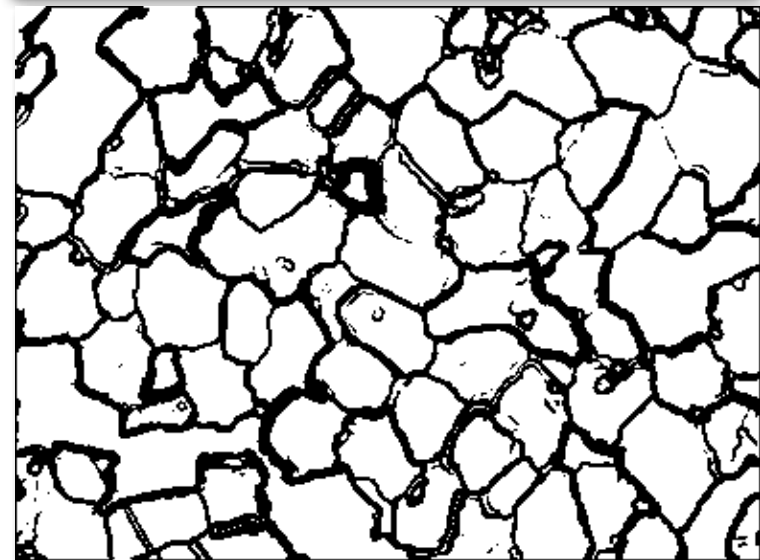


# segmentation: neighborhood operation

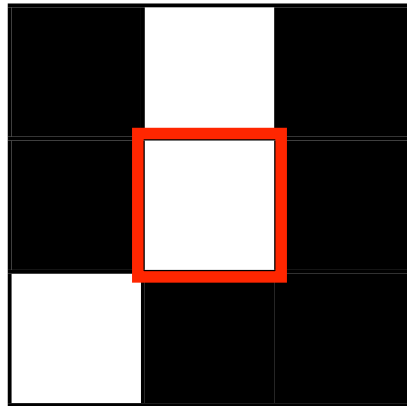


step 1  
segmentation  
basis = neighborhood (X,Y)  
⇒ grey scale image

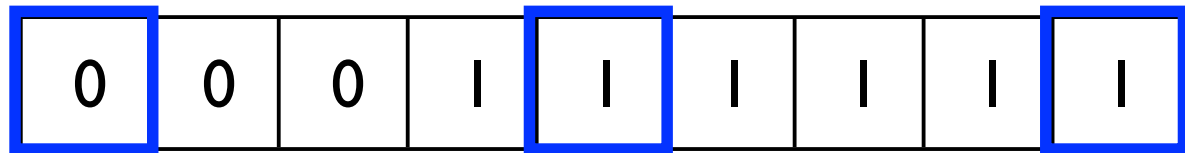
step 2  
thresholding - structural filtering



# ranking filters I



ranked grey values of 3x3 neighbourhood

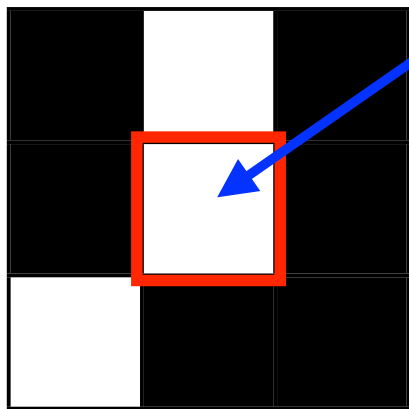


minimum

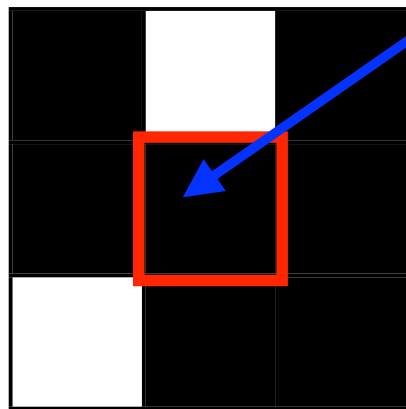
median

maximum

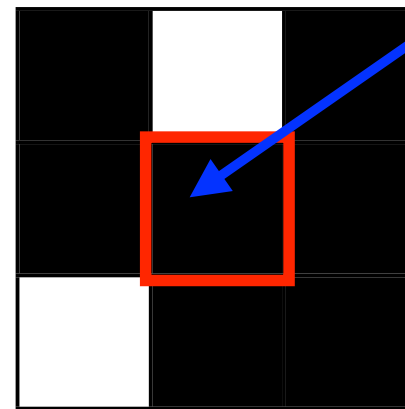
original



minimum

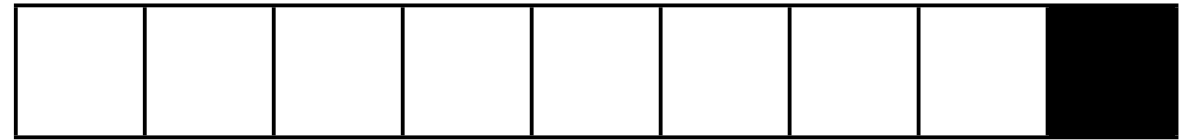
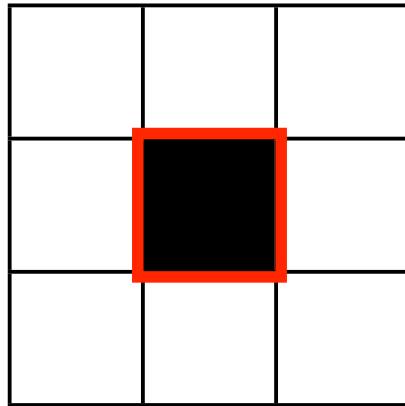


median

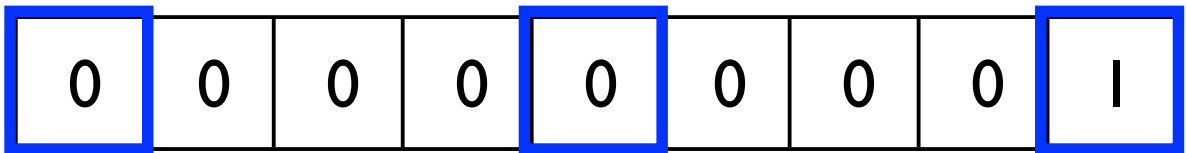


maximum

# ranking filters I



ranked grey values of 3x3 neighbourhood

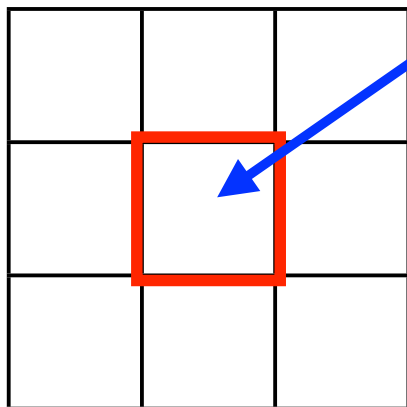


minimum

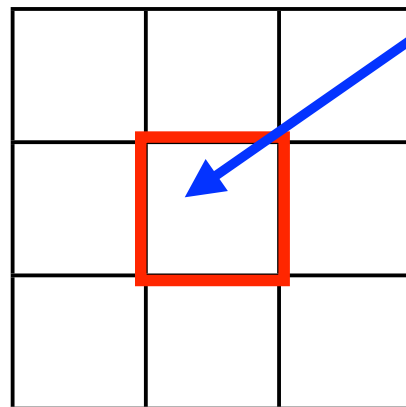
median

maximum

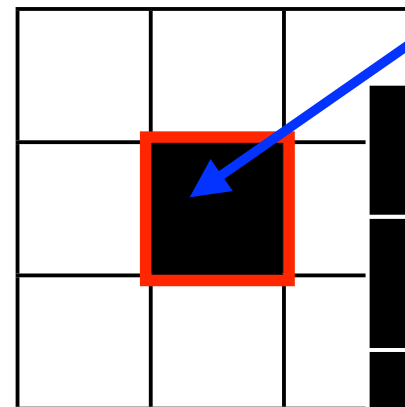
original



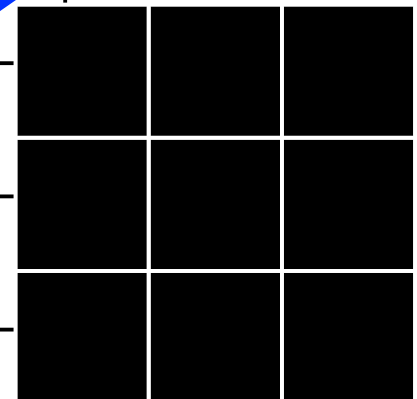
minimum



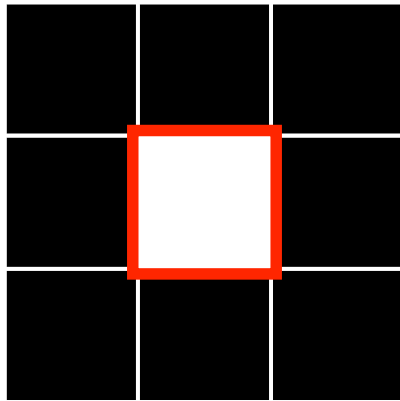
median



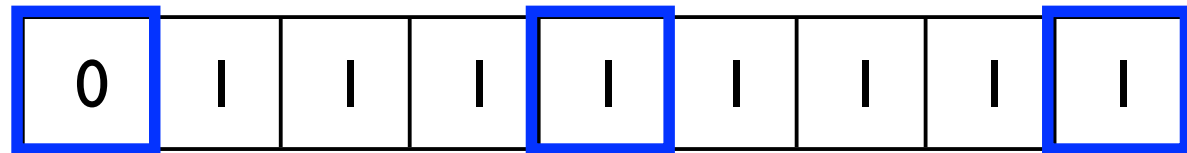
maximum



# ranking filters I



ranked grey values of 3x3 neighbourhood

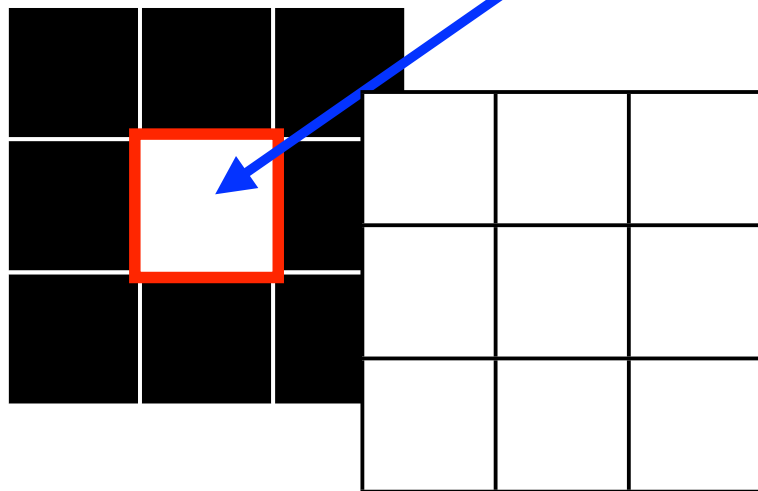


minimum

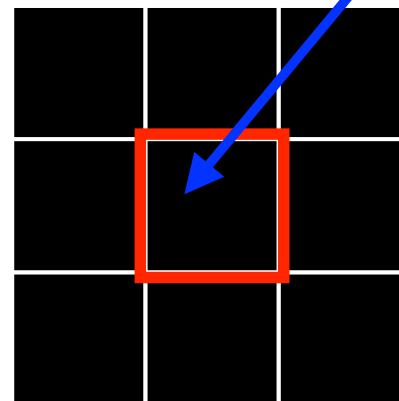
median

maximum

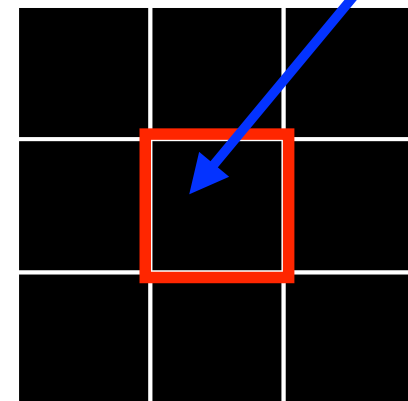
original



minimum



median



maximum



# ranking filters I

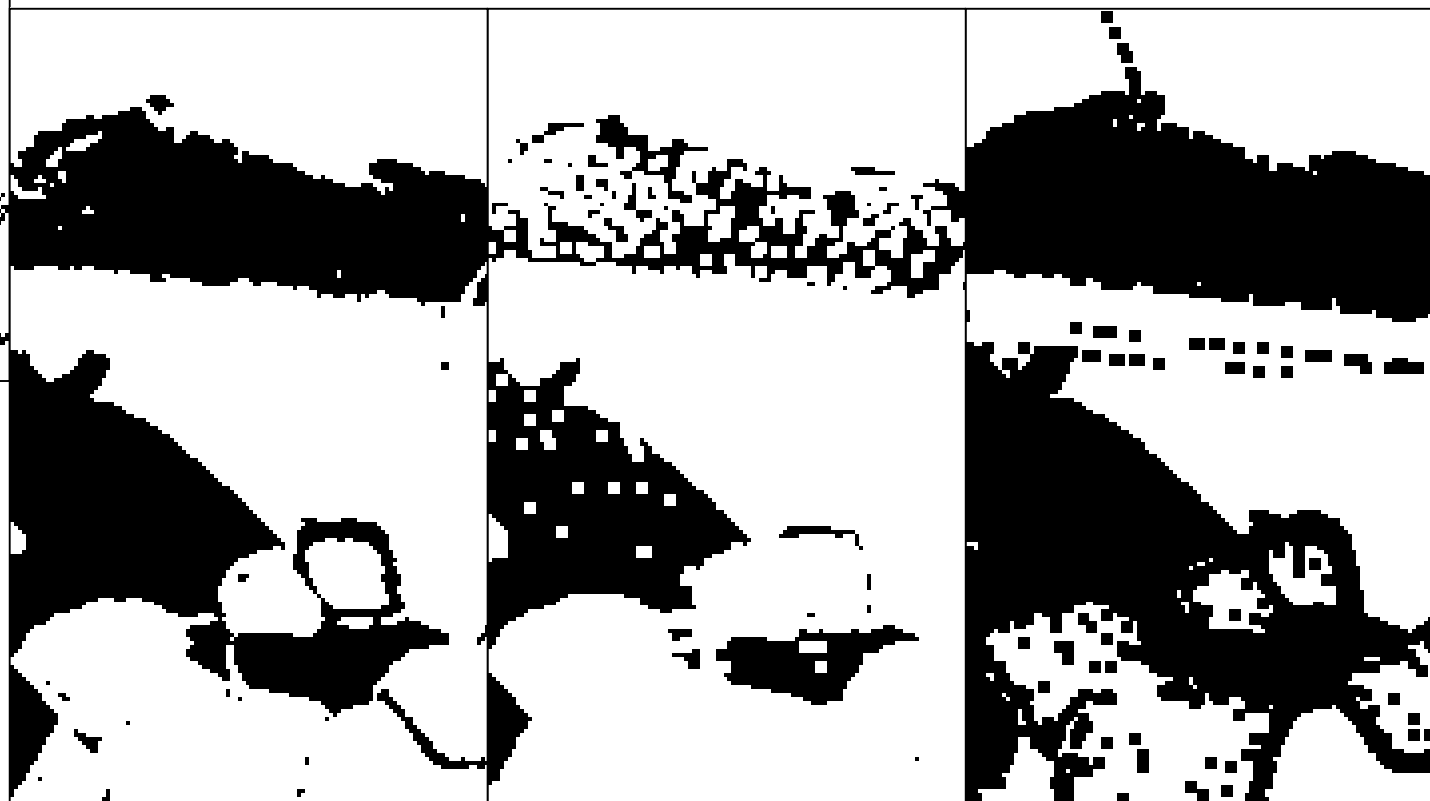


original

median

minimum

maximum

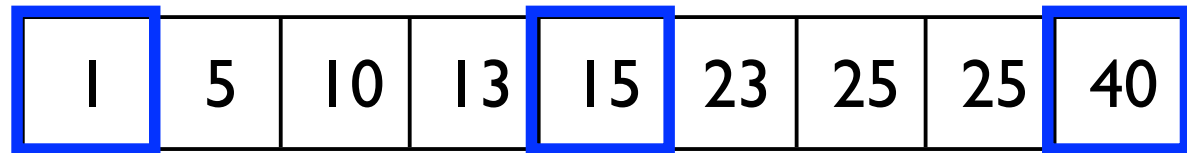


# ranking filters I for gray scale images

40	25	23
25	10	15
13	1	5



ranked grey values of 3x3 neighbourhood

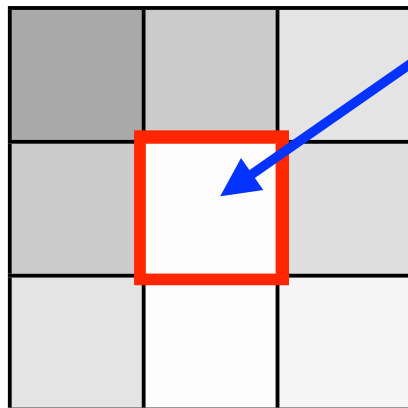


minimum

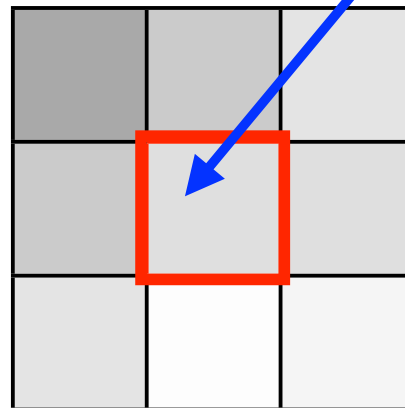
median

maximum

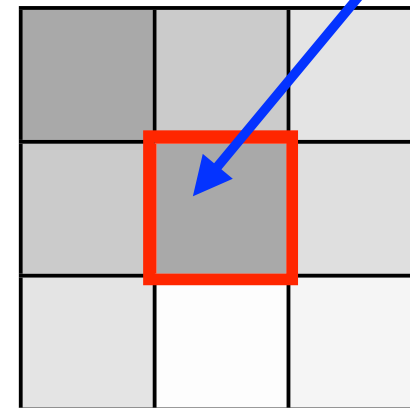
original



minimum



median

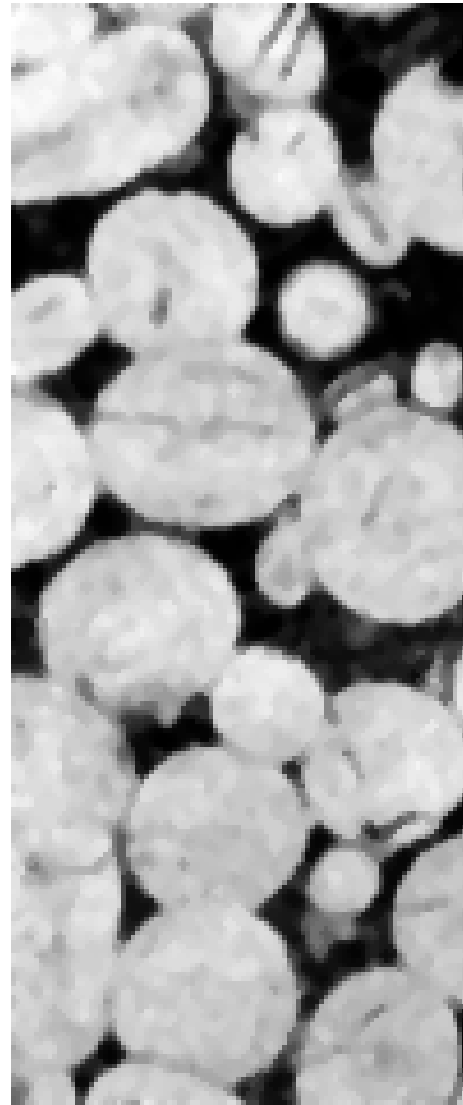


maximum

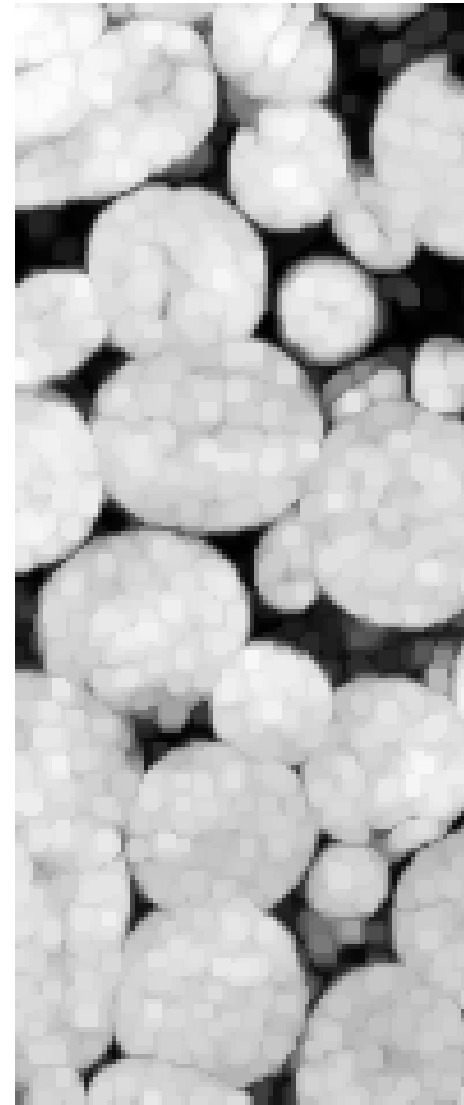
# ranking filters I for gray scale images



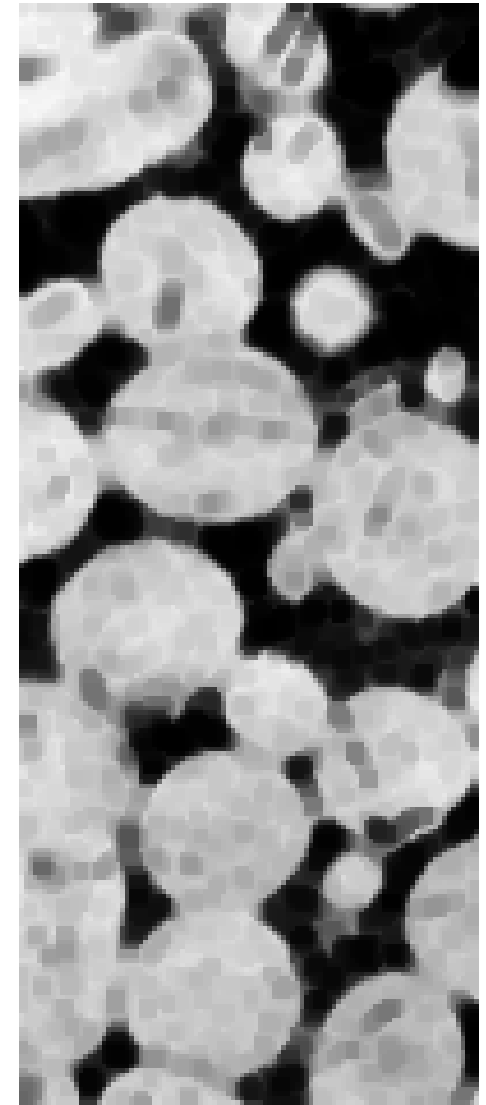
original



median

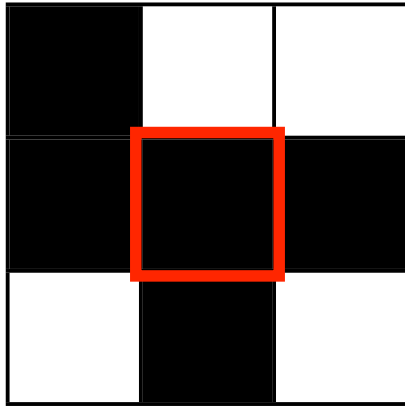


minimum



maximum

# ranking filters II



original



ranked grey values of 3x3 neighbourhood

## definition of neighbouring pixels

set count:

1 - erode if 1 is white

2 - erode if 2 are white

etc.

set count:

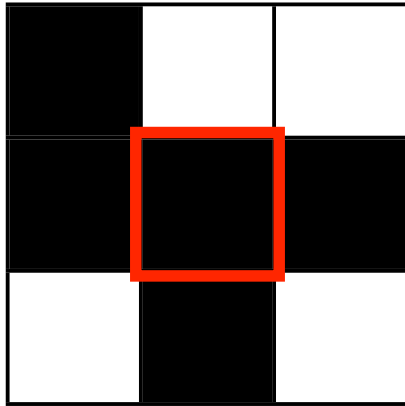
1 - dilate if 1 is black

2 - dilate if 2 are black

etc.



# ranking filters II



original



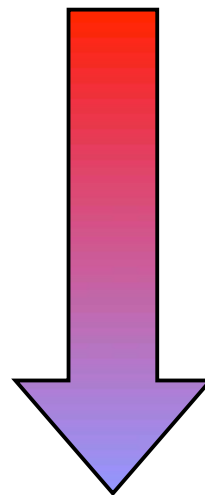
ranked grey values of 3x3 neighbourhood

strength of operation:

STRONG

Set Count:

- 1 - erode if 1 of 9 is white
- 2 - erode if 2 of 9 are white
- ....
- 8 - erode if 8 of 9 are white



WEAK

Set Count:

- 1 - dilate if 1 of 9 is black
- 2 - dilate if 2 of 9 are black
- ....
- 8 - dilate if 8 of 9 are black

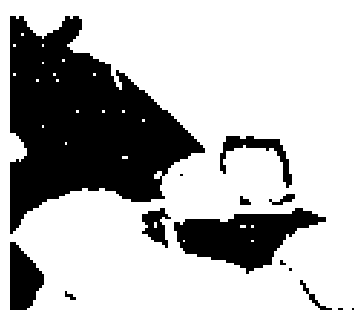
# ranking filters II



erosion



original



erode 7

erode 5

erode 3

erode

# ranking filters II



dilation



original



dilate 7



dilate 5



dilate 3



dilate

# morphological operations



original

1. erode  
2. dilate  
= opening

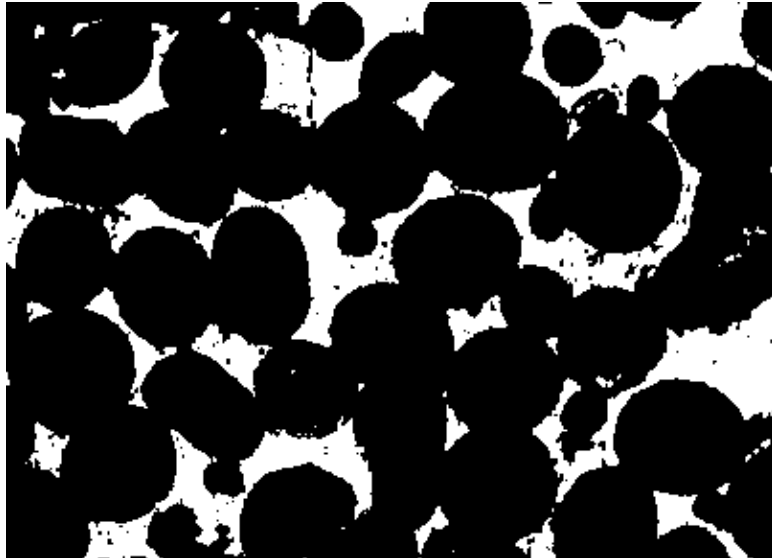


1. dilate  
2. erode  
= closing

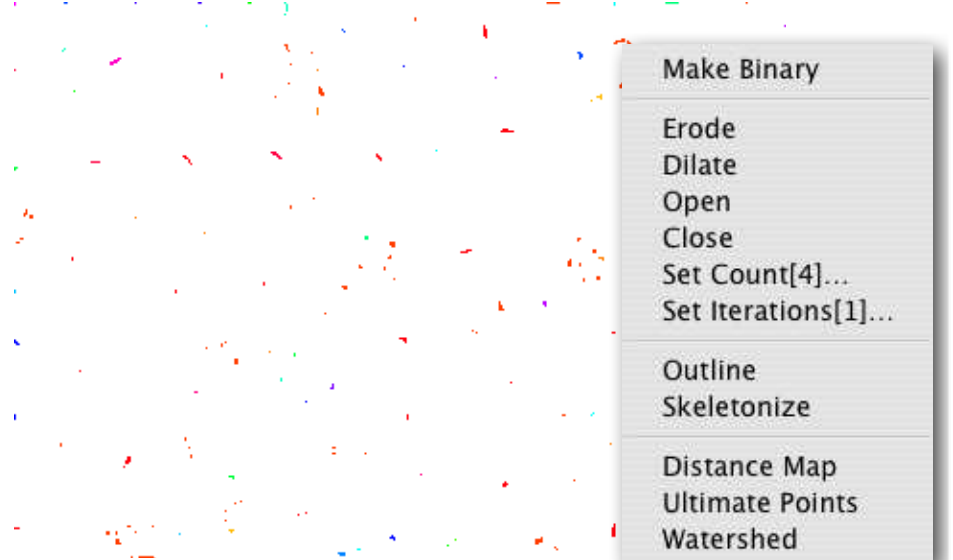




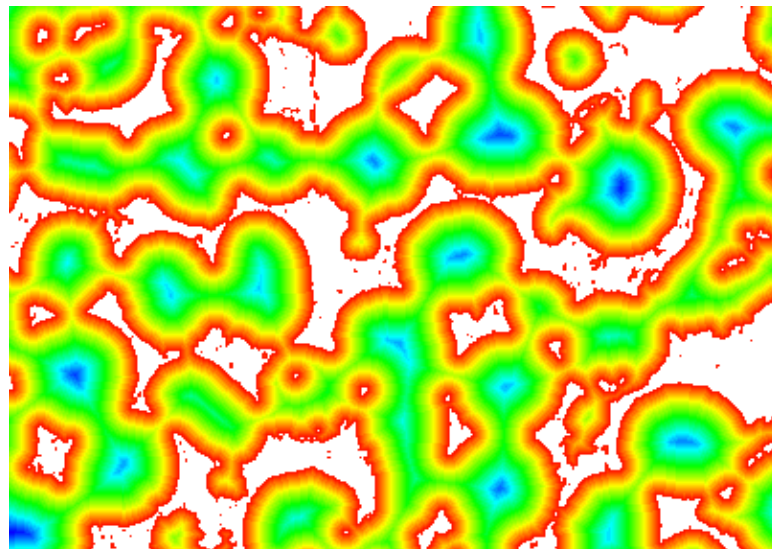
# morphological operations



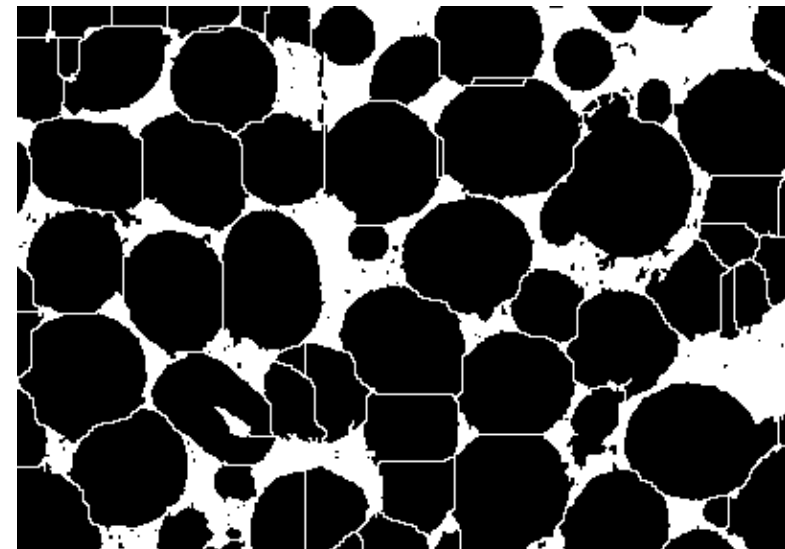
original



ultimate points



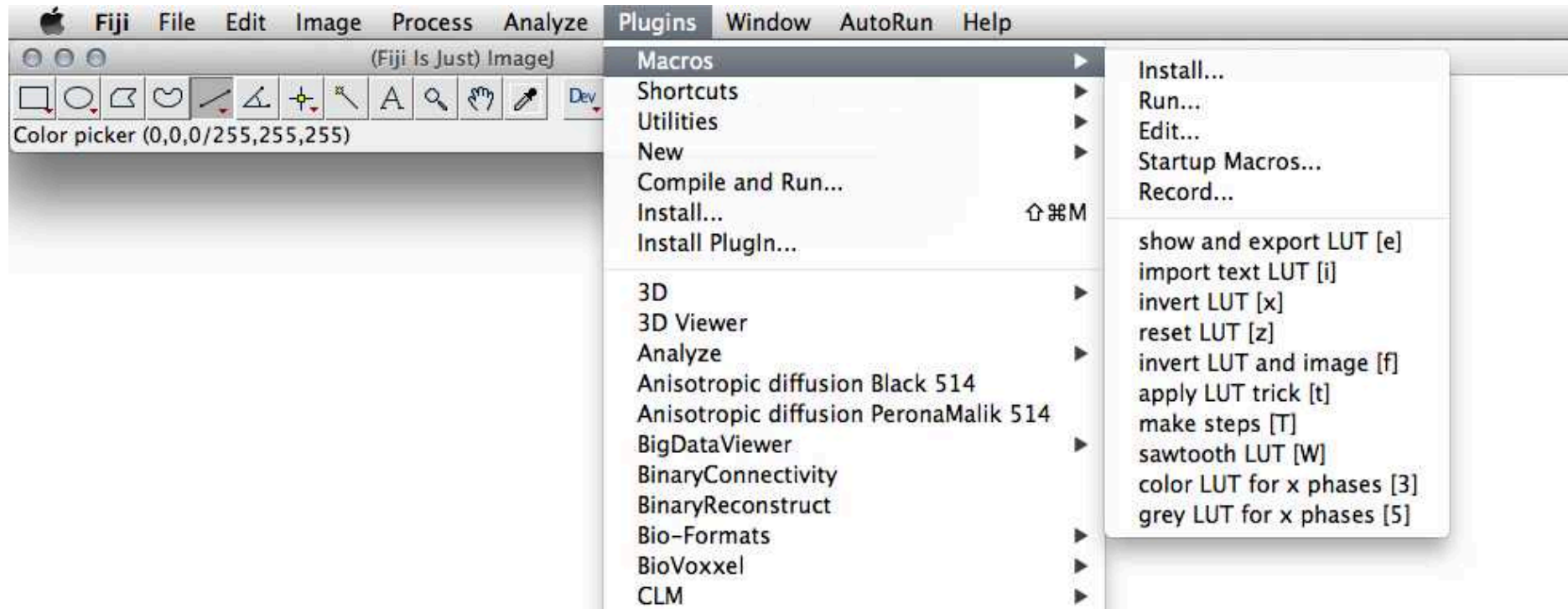
distance map



watershed

really quick  
introduction to  
Macros

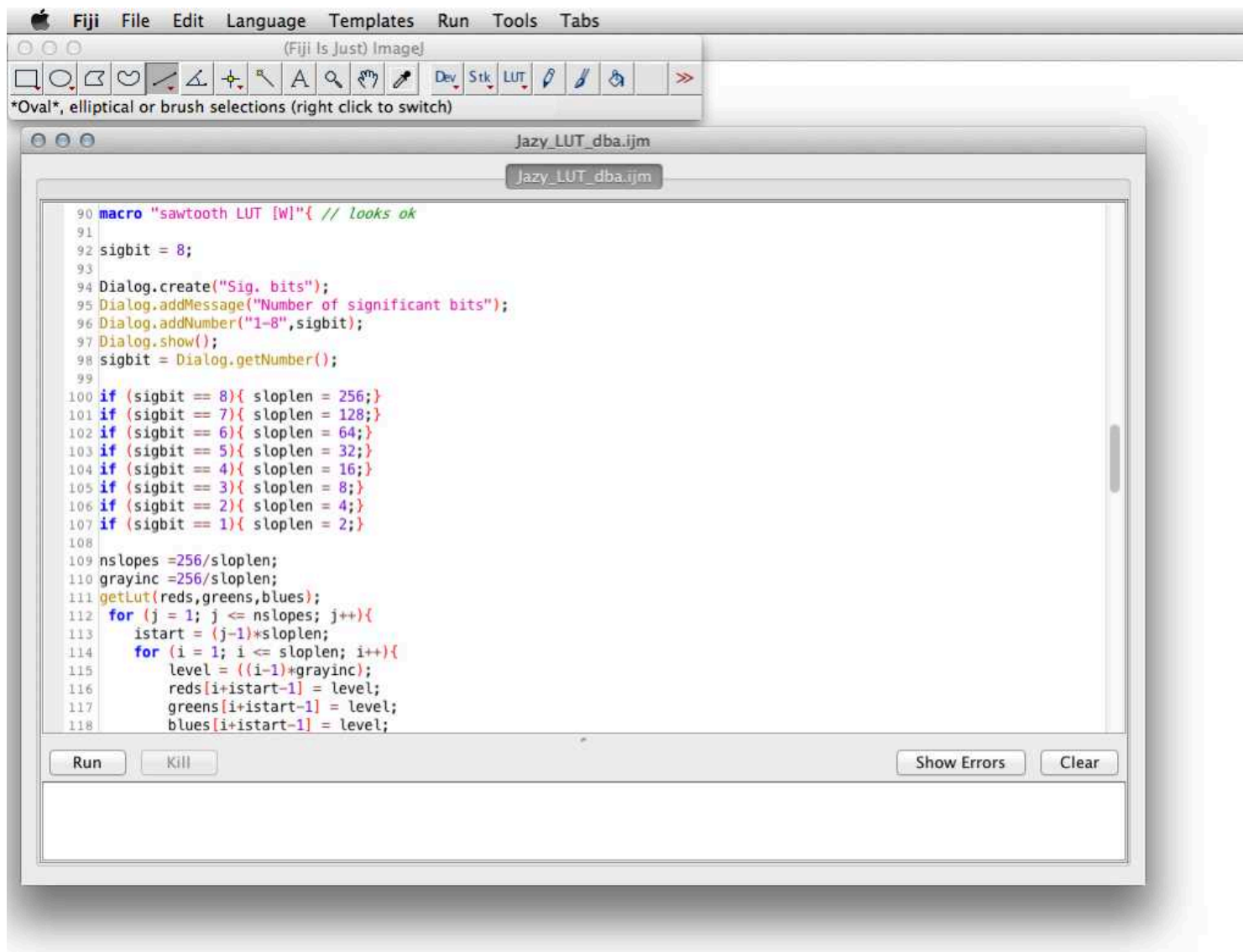
# Macro: Jazy\_LUT



<http://rsb.info.nih.gov/ij/developer/macro/macros.html>

<http://rsb.info.nih.gov/ij/developer/macro/functions.html>

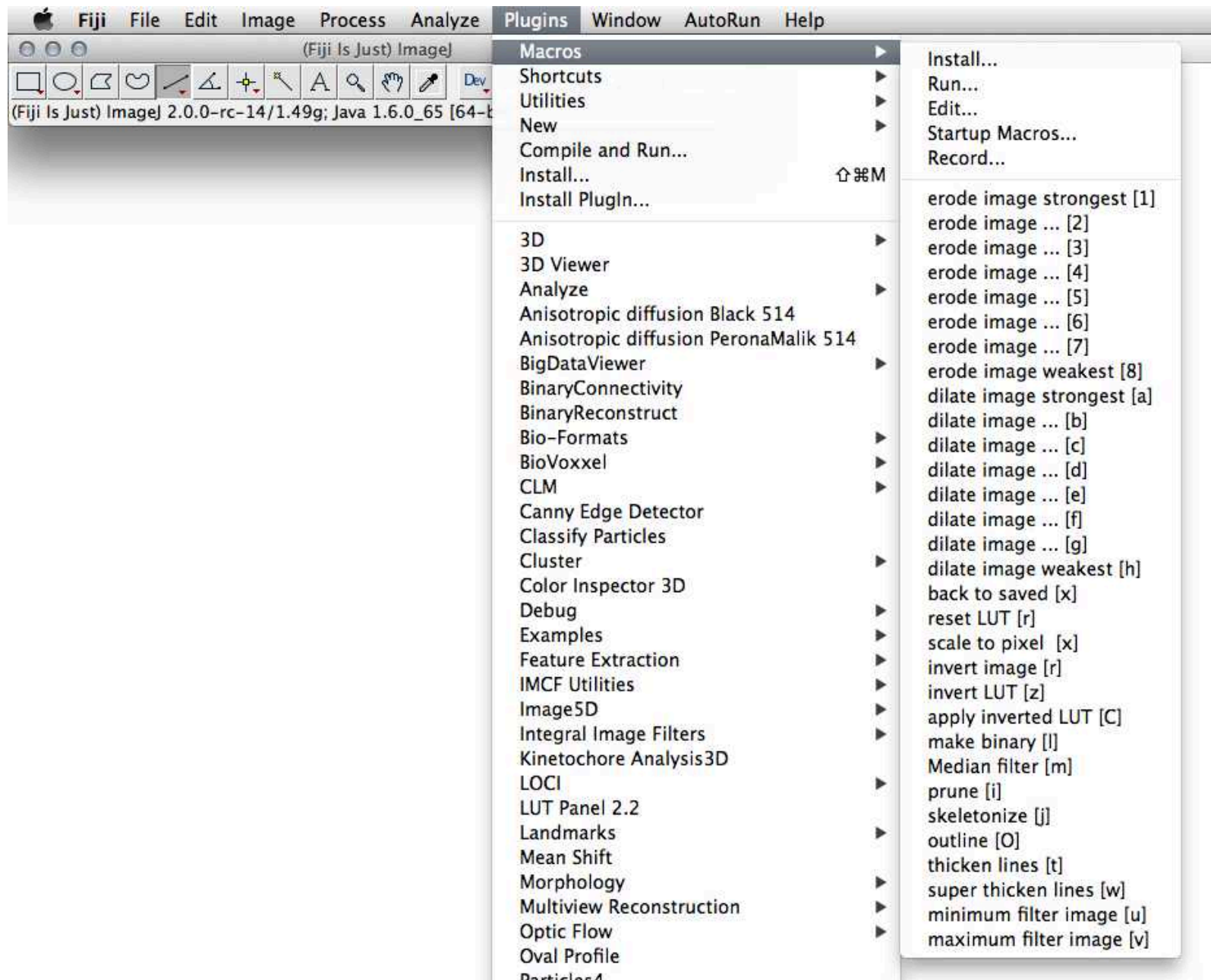
[http://fiji.sc/wiki/index.php/Introduction\\_into\\_Macro\\_Programming](http://fiji.sc/wiki/index.php/Introduction_into_Macro_Programming)



Select File > New > Script in the FiJi main menu, this will open the FiJi script editor:  
syntax highlighting, templates and output console

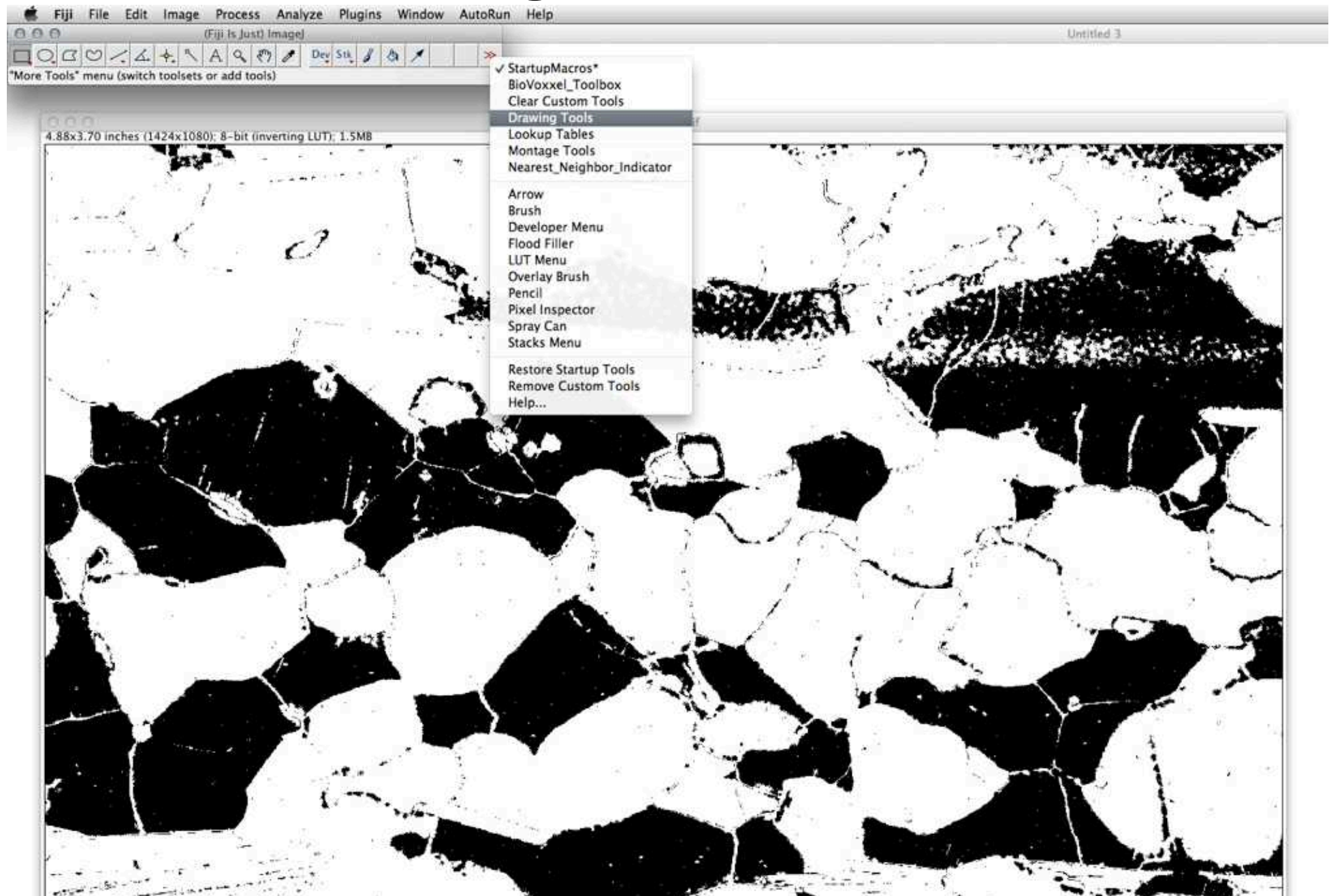


# Macro: Jazy erodilate (image)

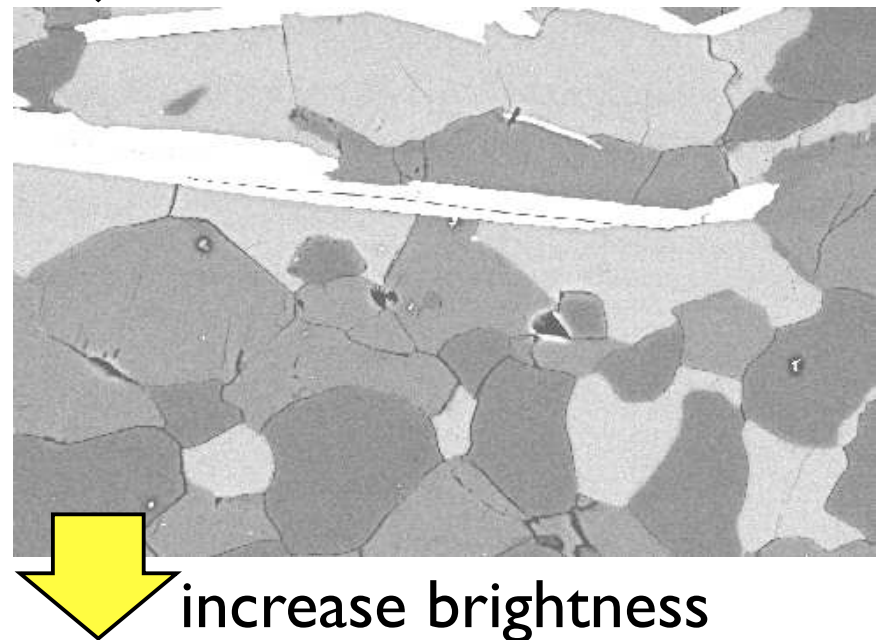
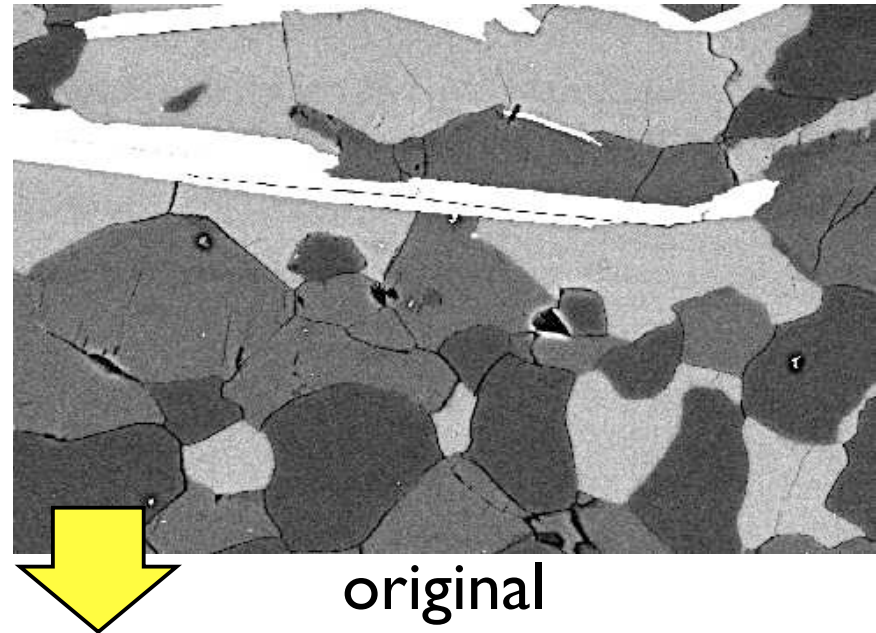
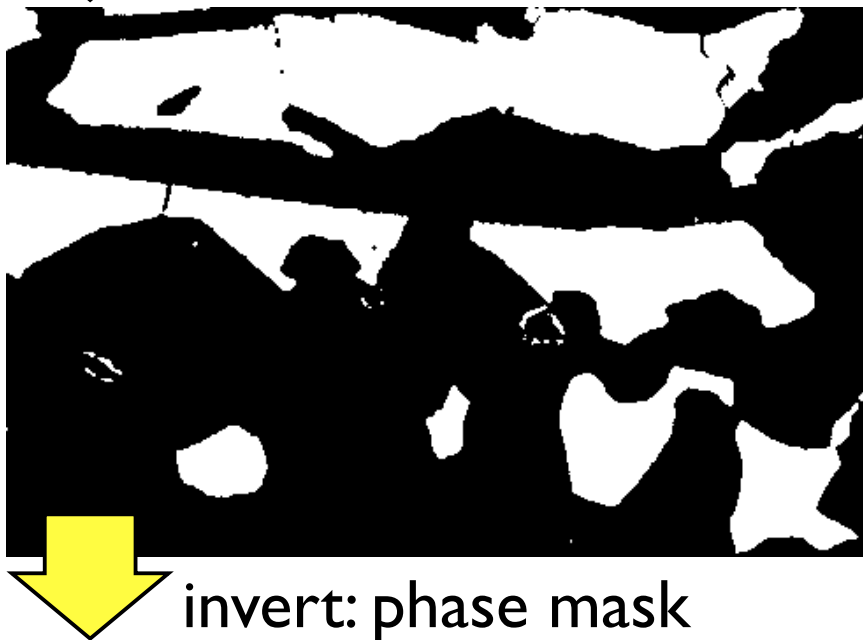
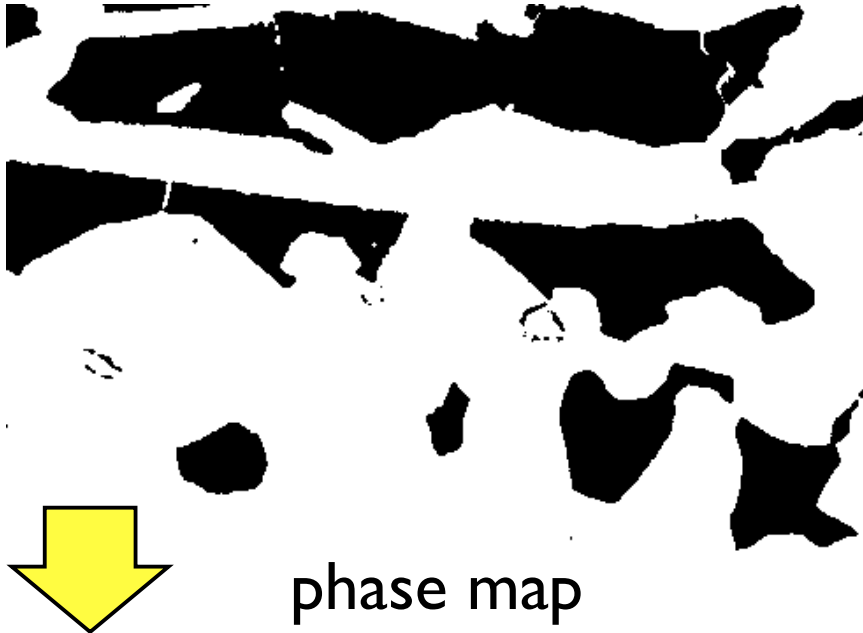


post-processing  
clean up  
segmentation

# manual cleaning

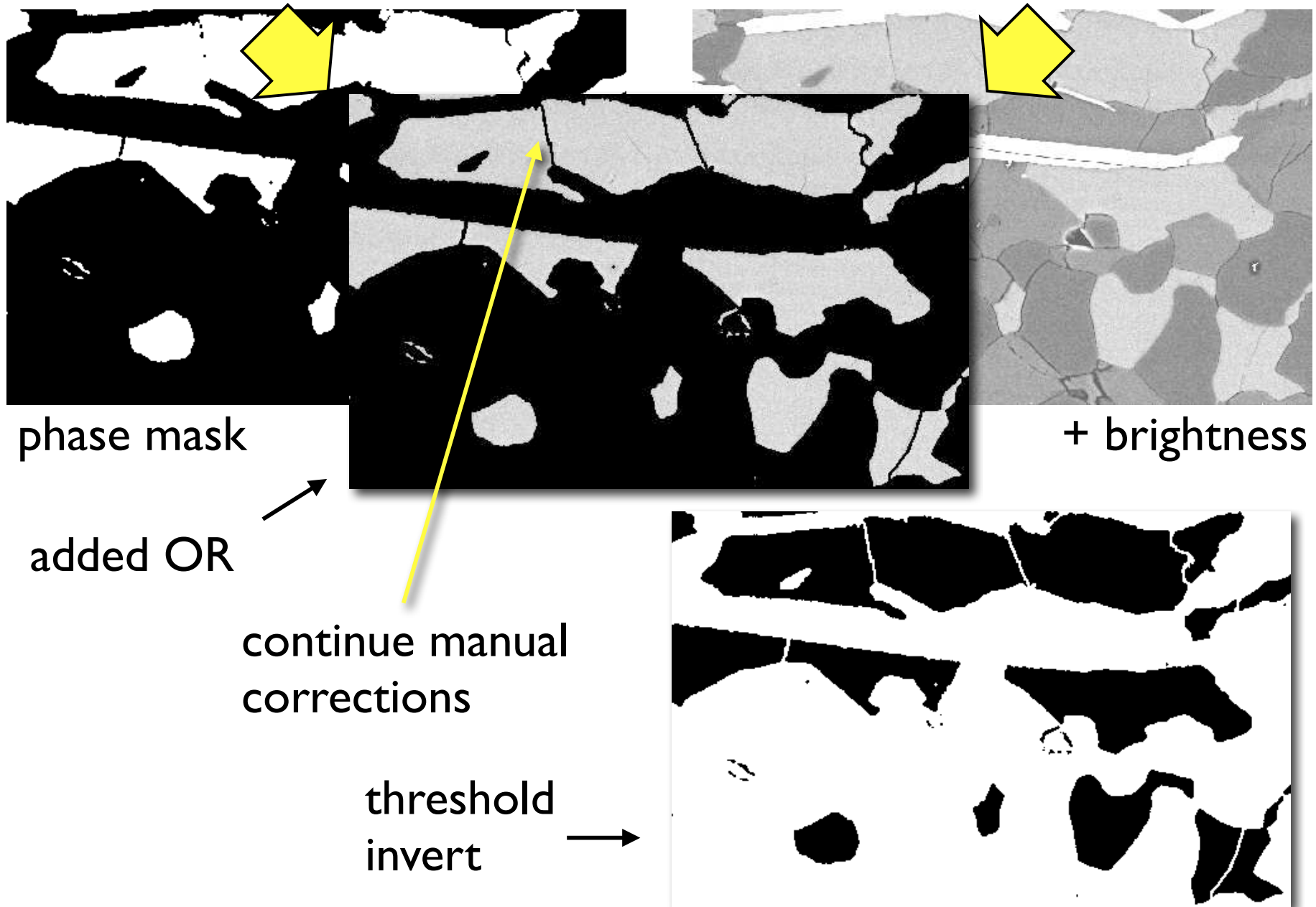


# cleaning in stack using phase masks

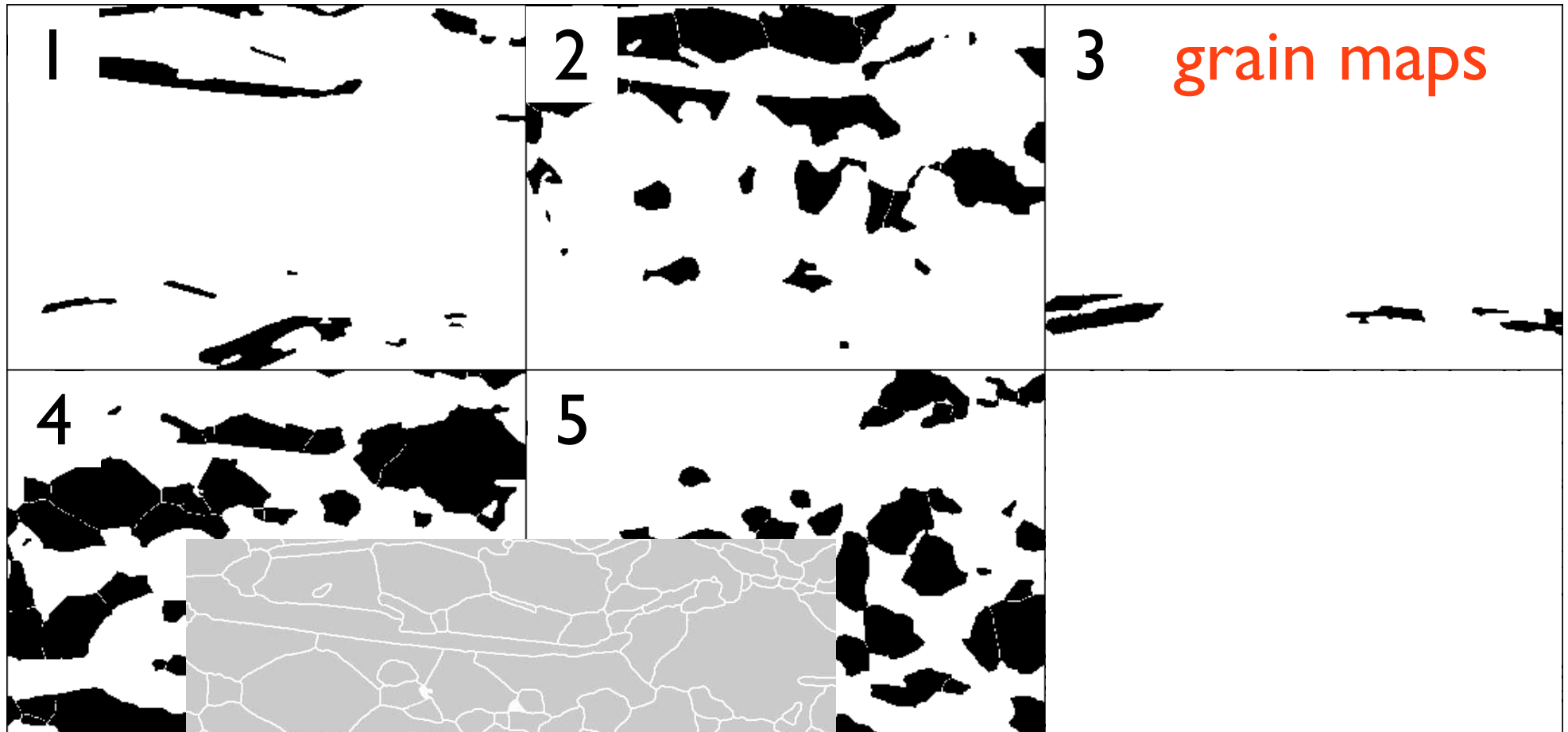




# merge mask and light version

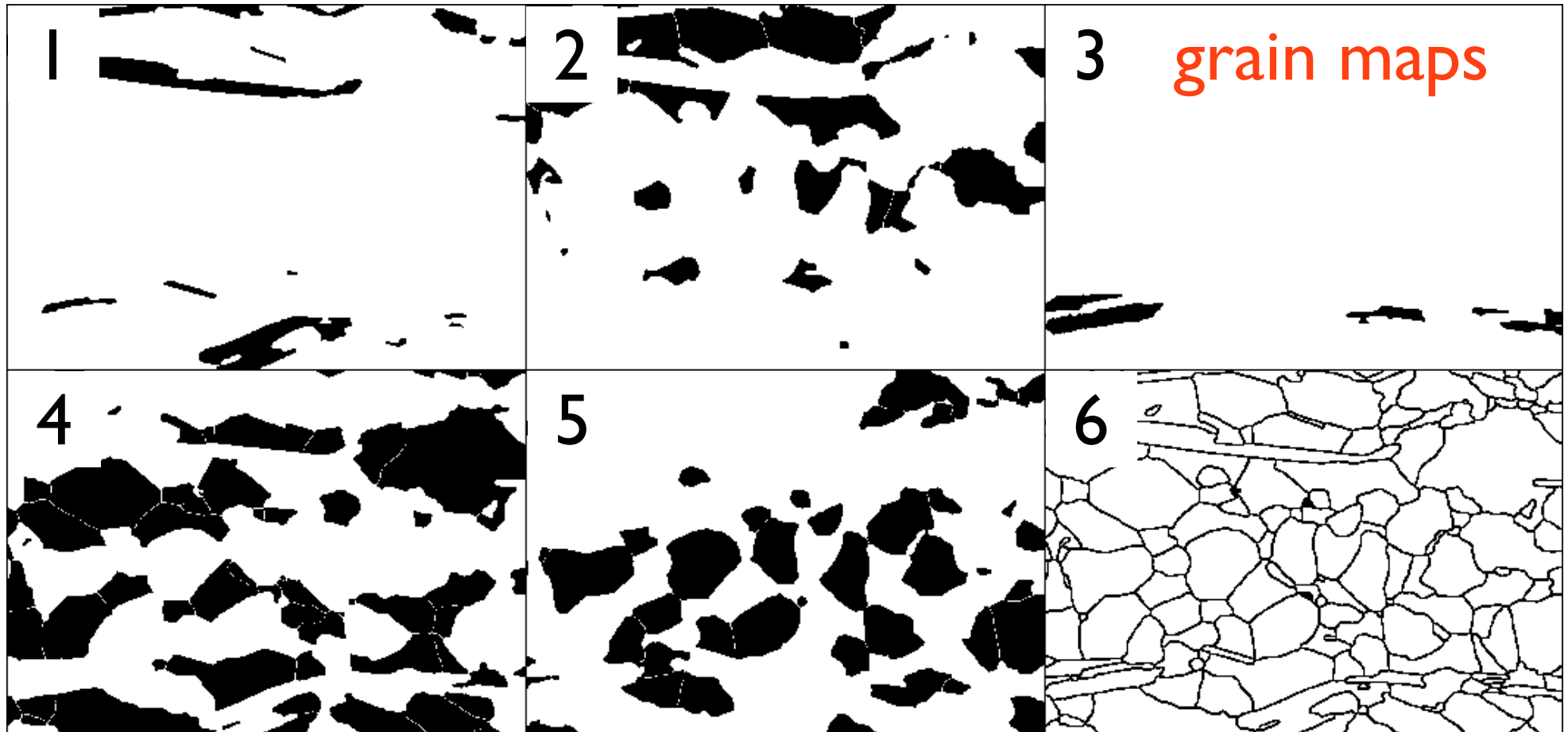


# procedure 1: separate grains ...

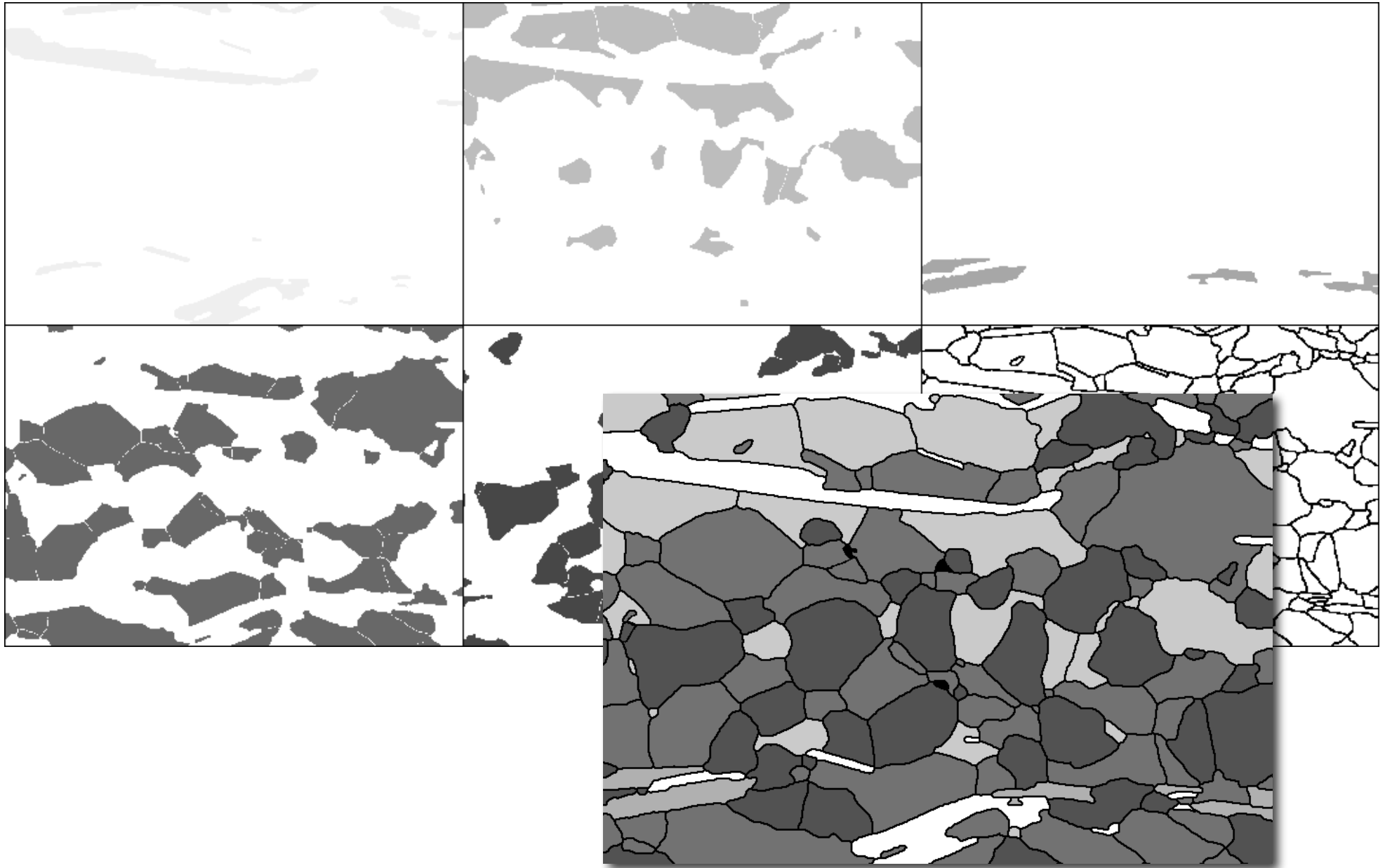


yields grain boundaries

# ... derive grain boundaries



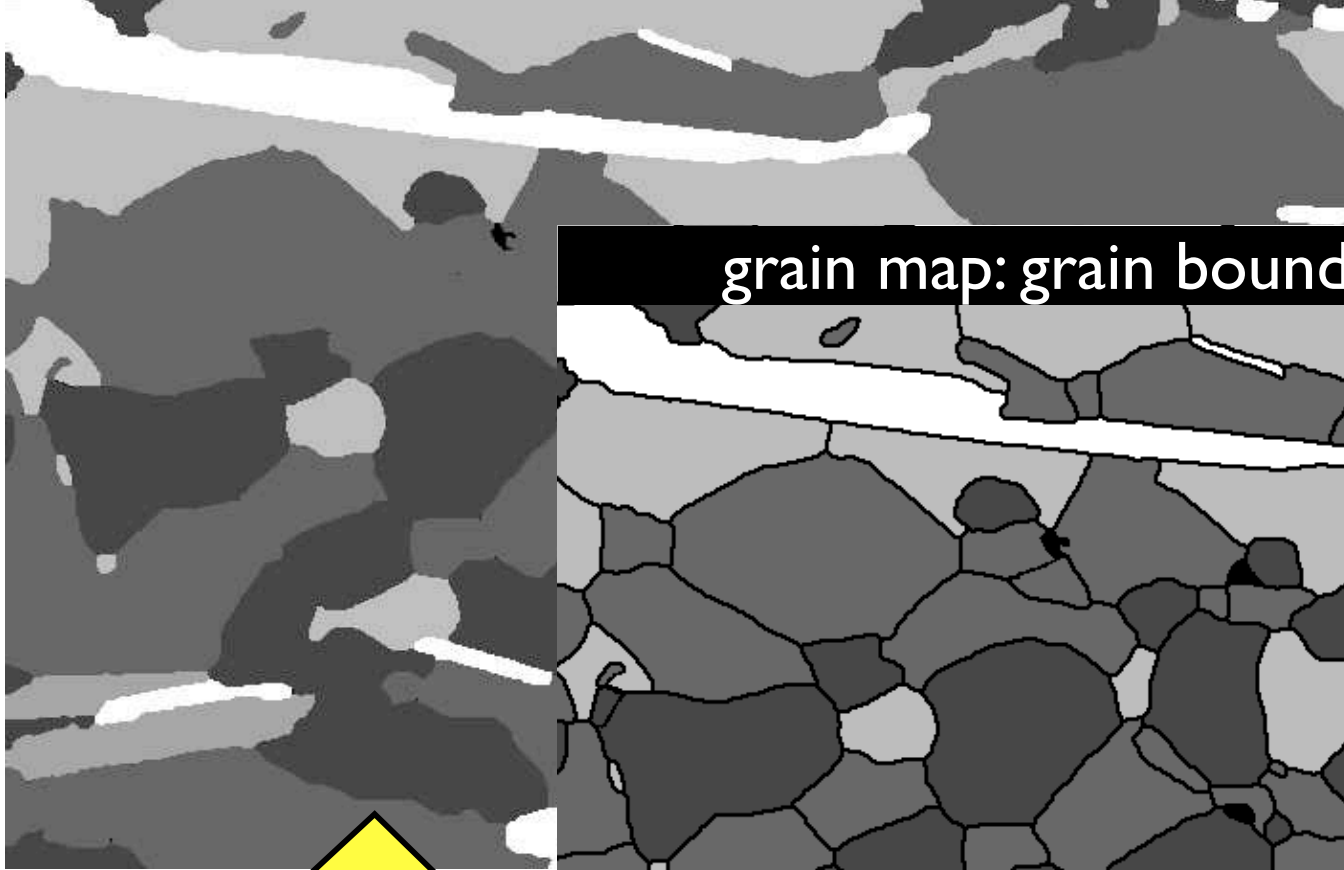
# using colored grain maps



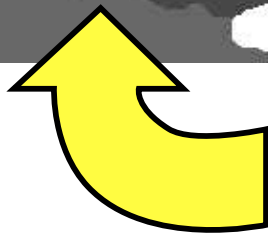
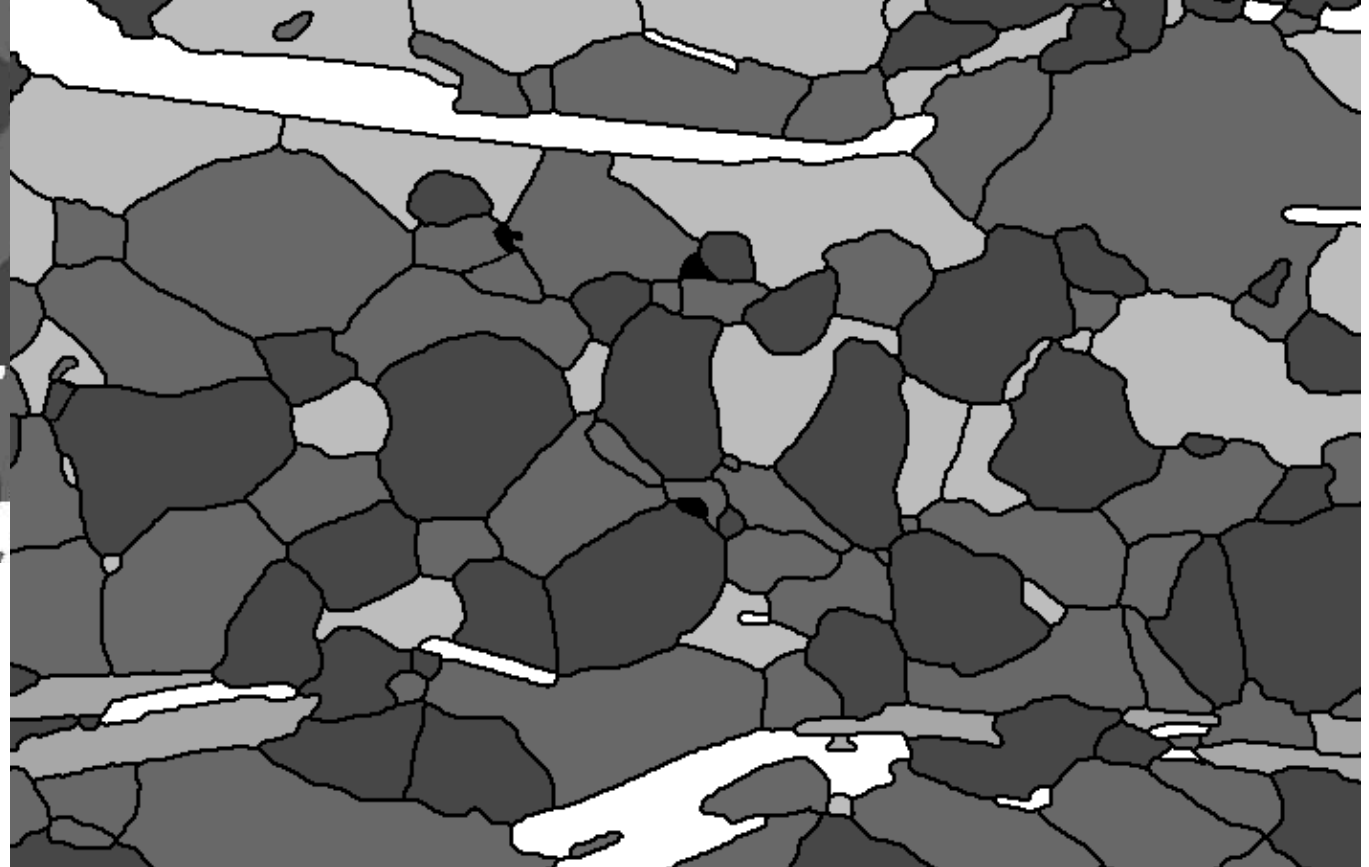


# derive phase map from grain map

phase map: no grain boundaries

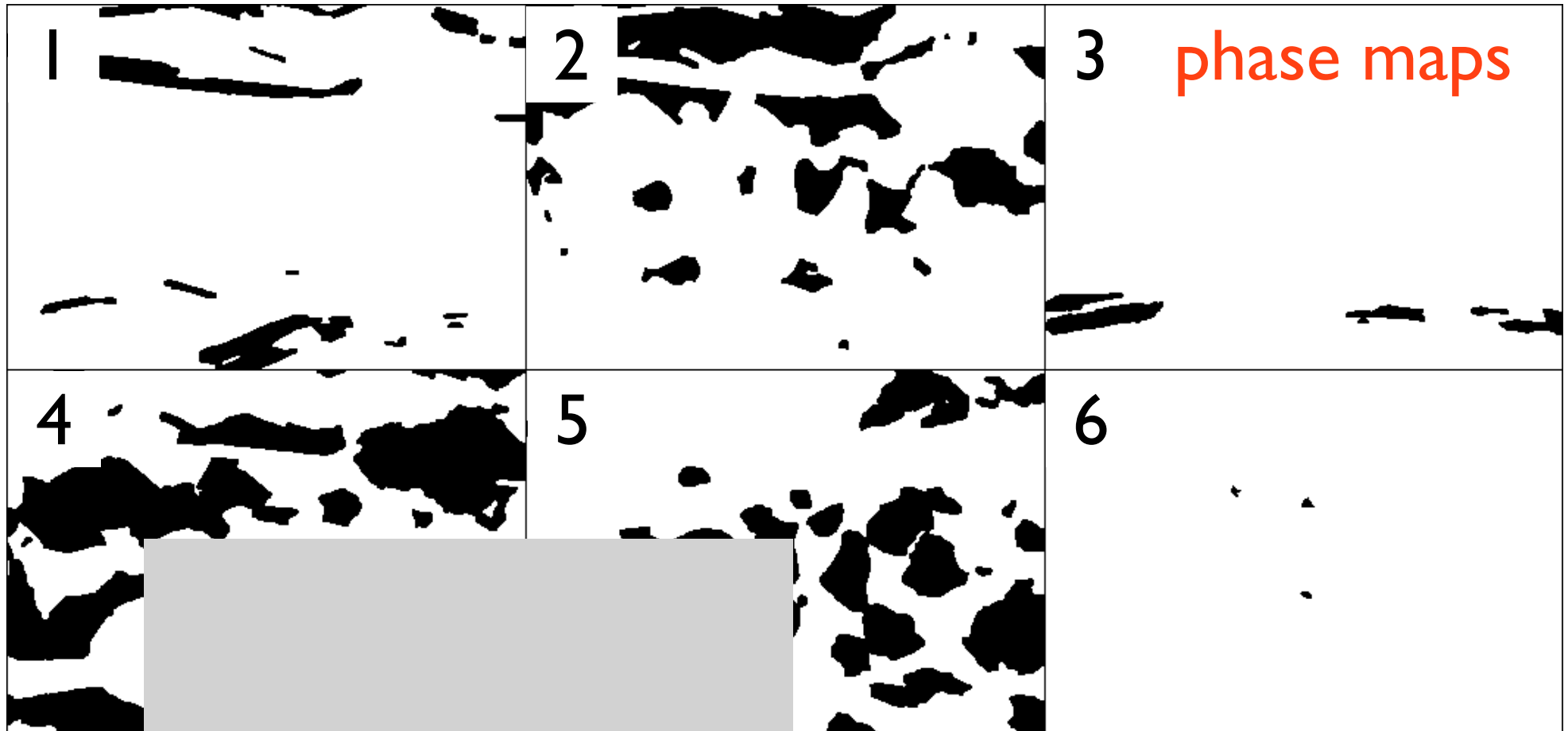


grain map: grain boundaries = 'phase'



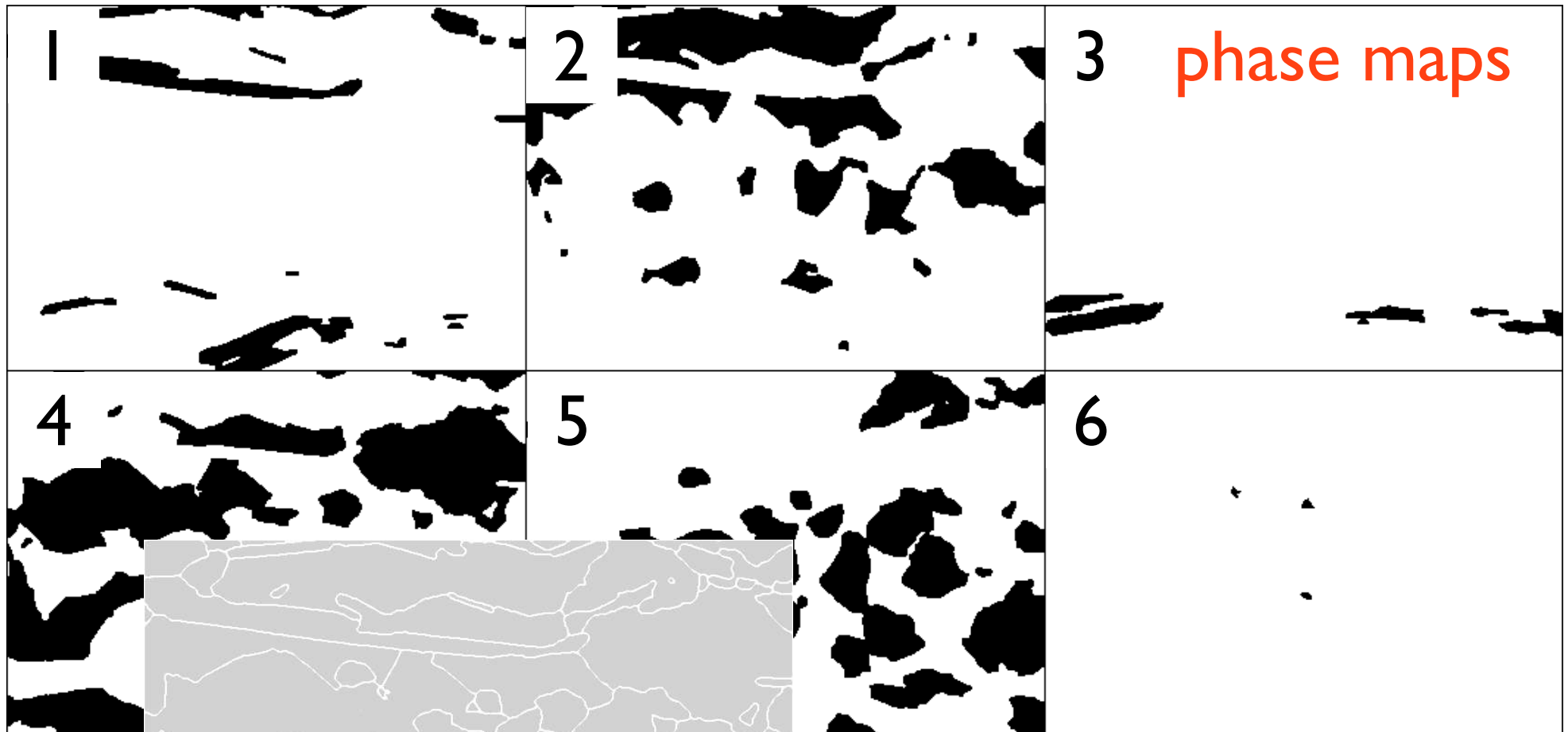
minimum filter

# procedure 2: separate phases ...



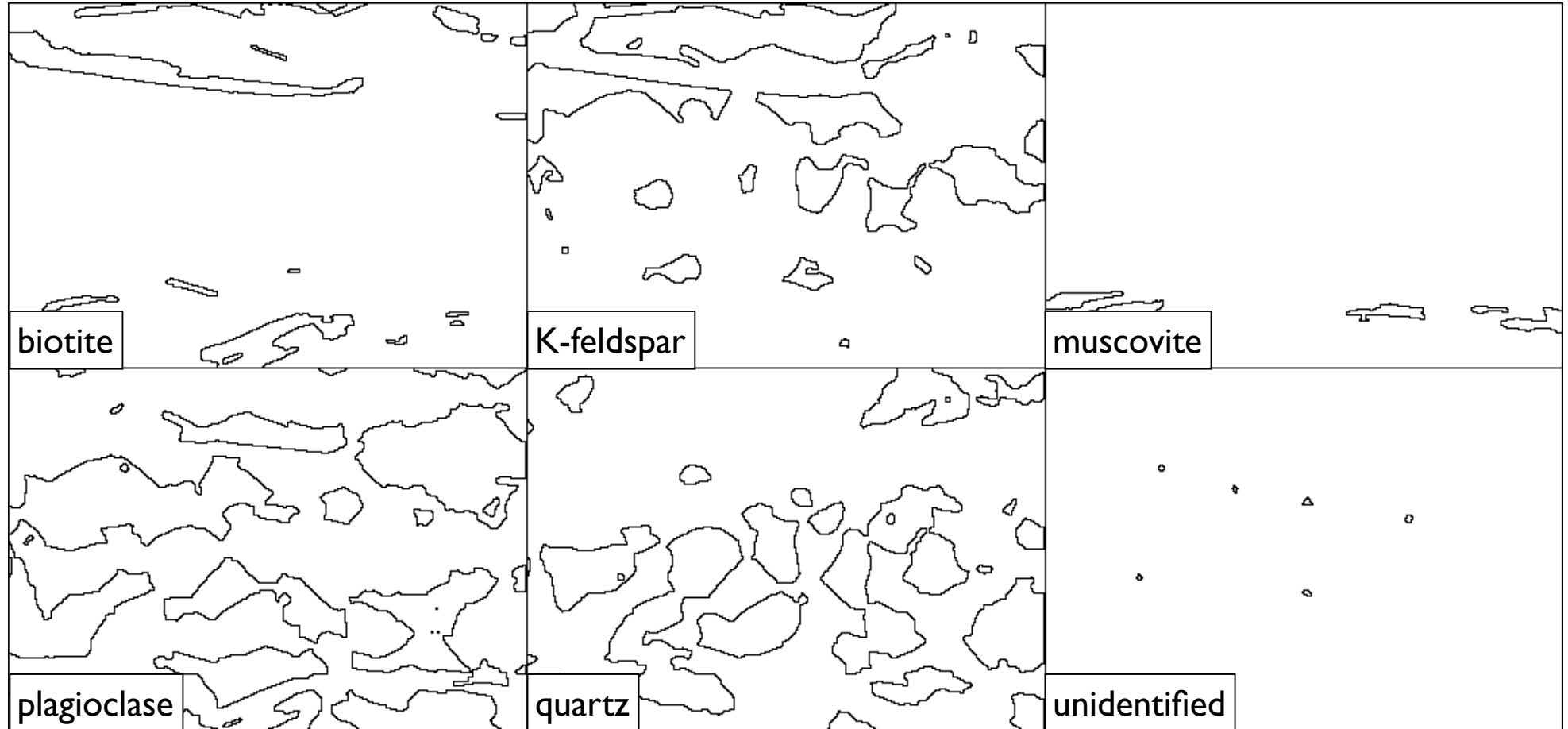
average all  
(incl. holes & unidentified)

# ... derive phase boundaries



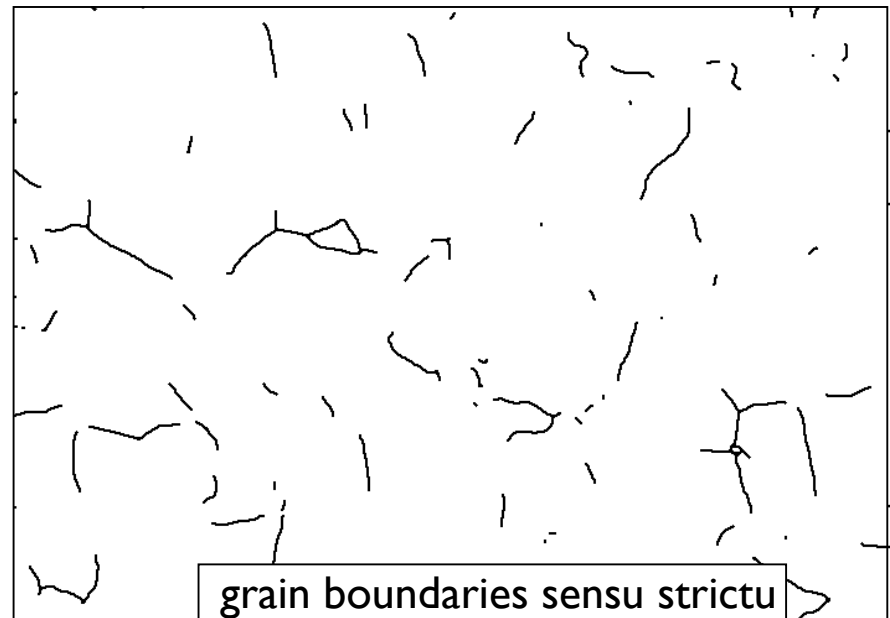
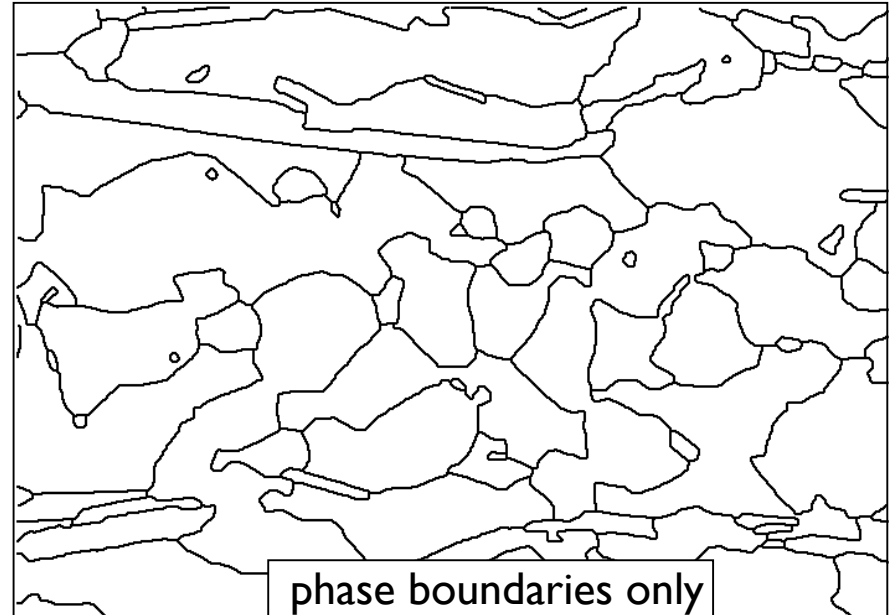
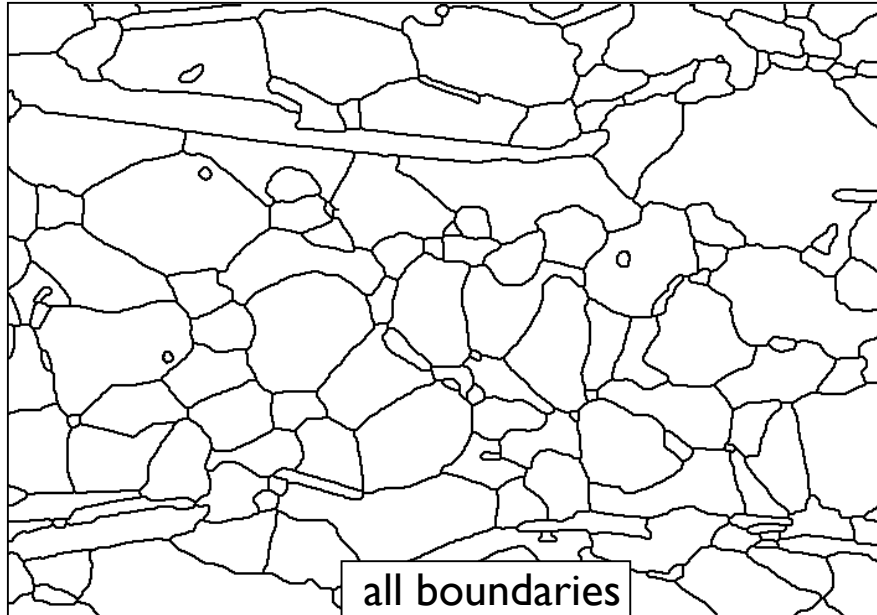
erode phases  
average

# phase boundaries





# phase vs. grain boundary maps



# Übung 10 - Post-processing

Segmentierung vervollständigen.

■ Führen Sie ein “post processing” an dem von Ihnen in der vorhergehenden Übung erstellten Stack durch.

Welche Verfahren wählen Sie?

Verwenden Sie Jazy erodilate (in imageJ) bzw. Lazy Erode Dilate (in ImageSXM)

# DBA 2014


## session 5

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
→ URZ - Universitätsrechenzentrum  
→ VIA - Vorlesungsverzeichnis  
→ PERSSEARCH - Personensuche

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Rock Deformation Projects & Software Workshops Textbook DDM Macros ImageJ Macros ImageJ Kiviat

LEHRVERANSTALTUNGEN



...le ciel n'est pas "L'appel des cimes" de René Magritte...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehalle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageDXM bzw. ImageJ kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageDXM software (MacOSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Estimation (2-D -> 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formalanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software Image DXM, bzw. ImageJ (alle public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungsbeitrag möglich)
- Harterter, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET** earth.unibas.ch  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

TROMSØ GEOMAGING

→ TROMSØ CRUSTAL DYNAMICS HOMEPAGE (English)  
→ TROMSØ GEOLOGY HOMEPAGE (Norwegian)  
→ TROMSØ UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>

# Semesterfahrplan: Fahrplanänderung

			Freitag CR 14-17	Montag CR 14-17
	Thema	Doz.	Gruppe A	Gruppe B
1	Images for image analysis - intro: ImageSXM	RH	19-Sep-2014	22-Sep-2014
2	Digital Images - Pixels - LUTs	RH	26-Sep-2014	29-Sep-2014
3	Explore / pre-process digital images - intro: imageJ	RK	3-Oct-2014	6-Oct-2014
4	POP segmentation - post-processing	RK	10-Oct-2014	13-Oct-2014
5	Mathem./Punkt-Operationen Verschneide-Operationen	RH	17-Oct-2014	
		RH		27-Oct-2014
	(fällt aus)			
			nur Freitag CR 14-17	
6	Filtern - Kantendetektion - NOP segmentation	RH	7-Nov-2014	
7	Analyze: segments - best-fit ellipses - property maps	RH	14-Nov-2014	
8	Fourier-Transformationen Autokorrelation	RH	21-Nov-2014	
	(Dies Academicus)			
9	Korngrößen-Analyse Stereologie - Kontaktflächen	RH	5-Dec-2014	
Test			12-Dec-2014	

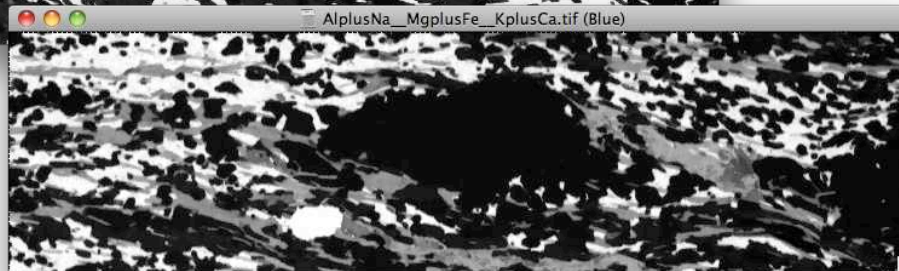
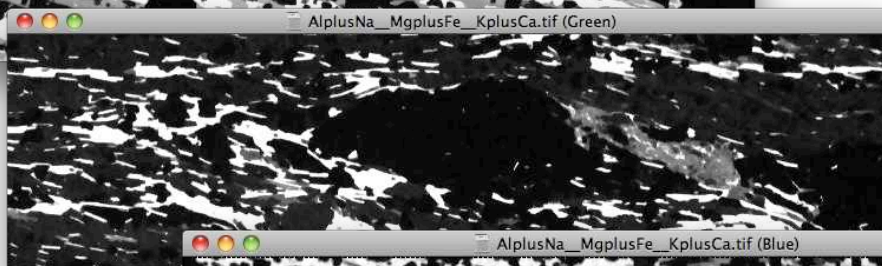
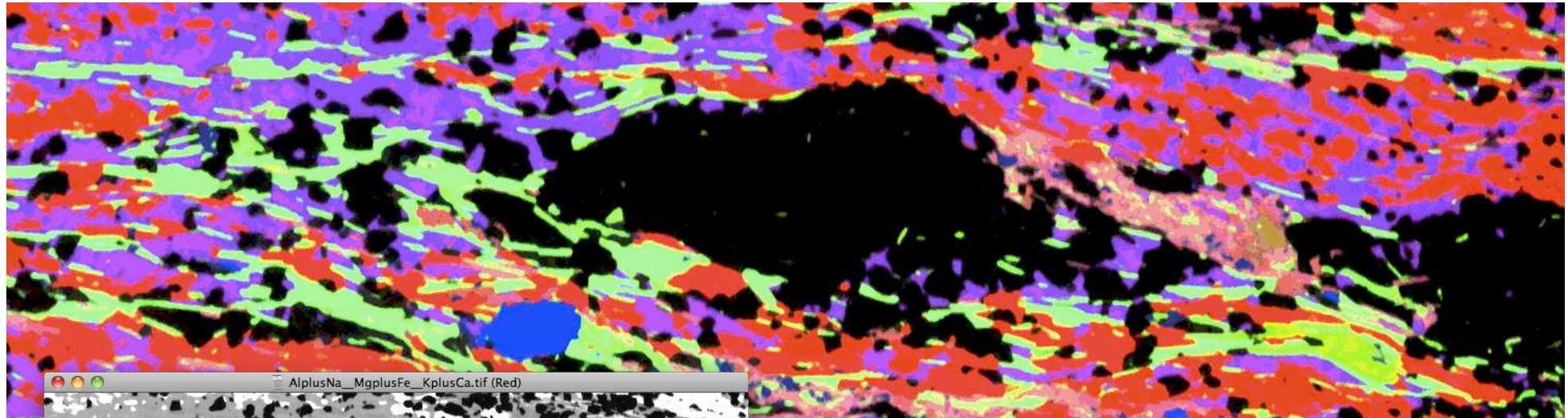
pro Nachmittag: 1. Teil: Vorlesung (Einführung in das Thema) - 2. Teil: Übungen  
Besprechung der Übungen am Anfang der nächsten Vorlesung



# Verschneide- operationen

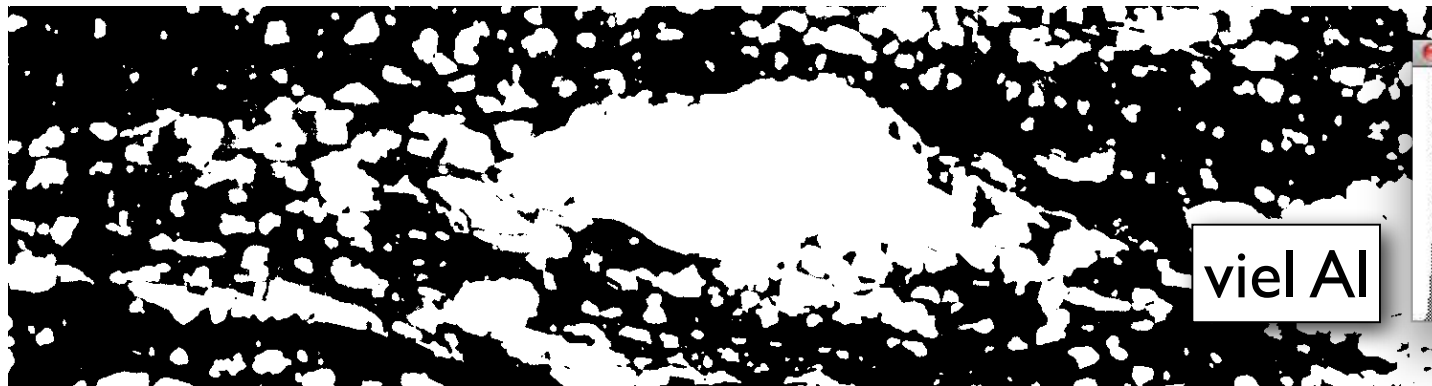
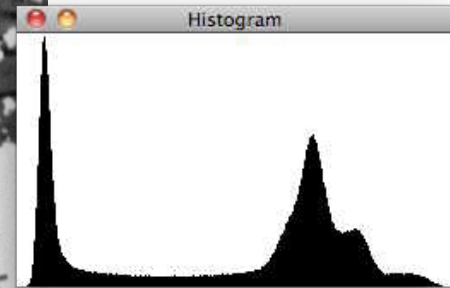
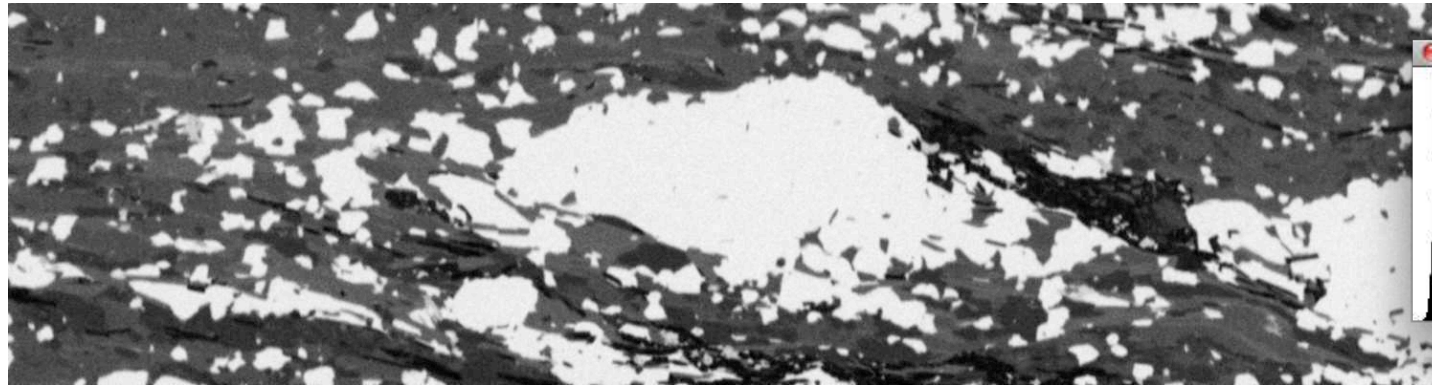
# Übung 8 - Verteilungsbilder (RGB)

Wir nehmen nochmals die Elementmaps hervor

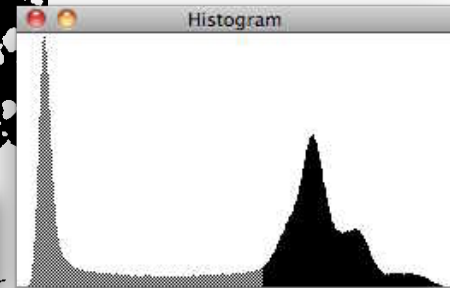


schwarz = Qtz  
rot = Plg  
lila = Kfs  
grün = Bt  
blau = Ap  
lachs = Wm

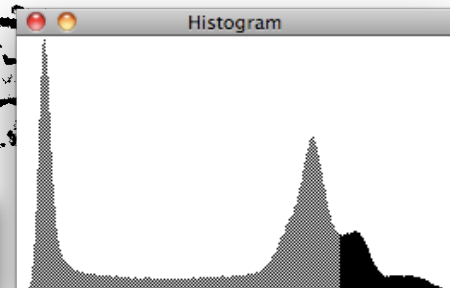
# element maps



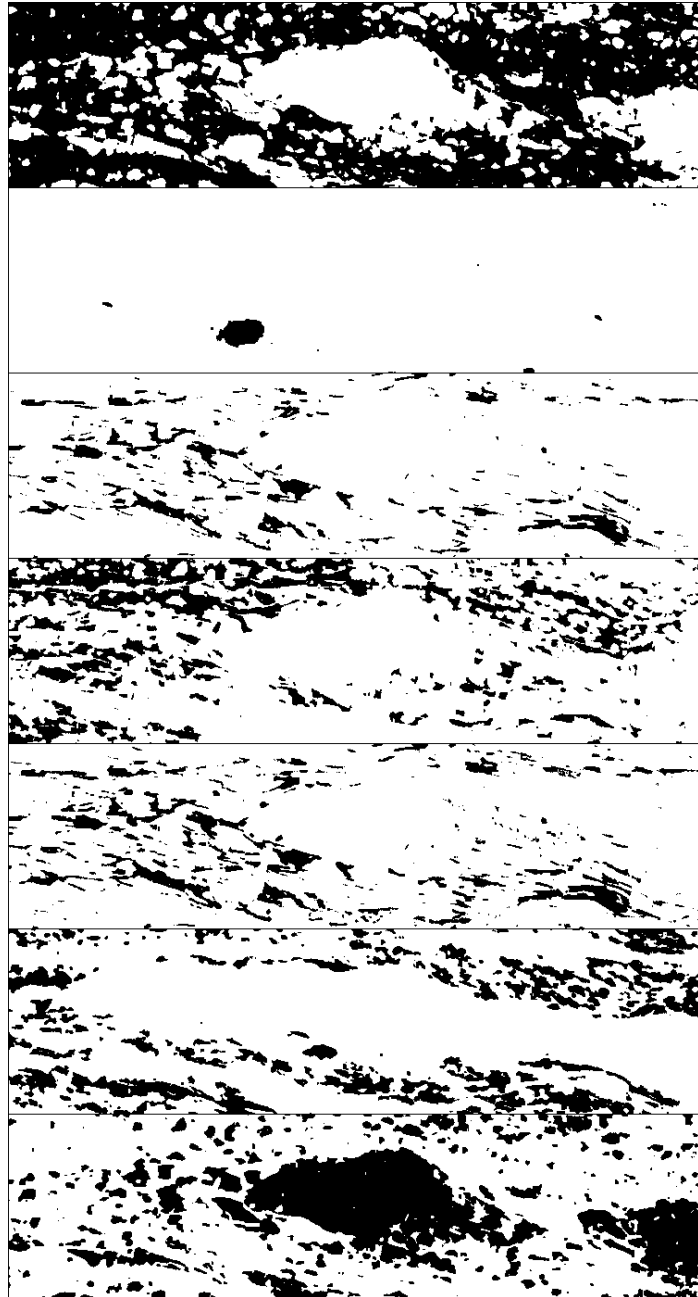
viel Al



sehr viel Al



# element bitmaps



Al

Ca

Fe

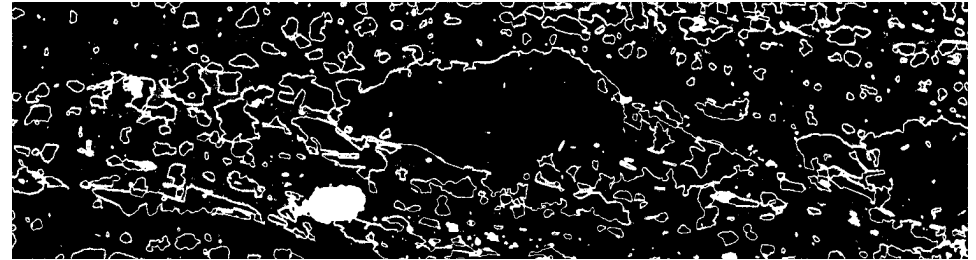
K

Mg

Na

Si

Phase with Al or Si

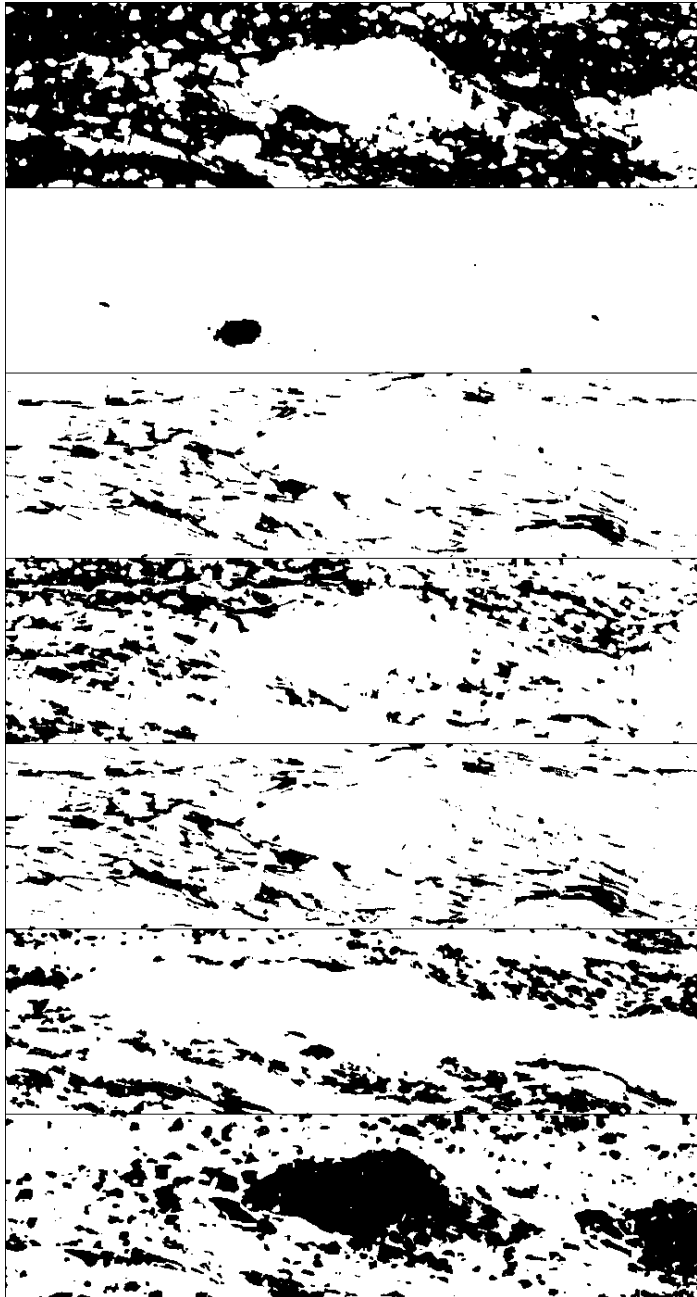


Phase with Al and Si





# element bitmaps



Al

Ca

Fe

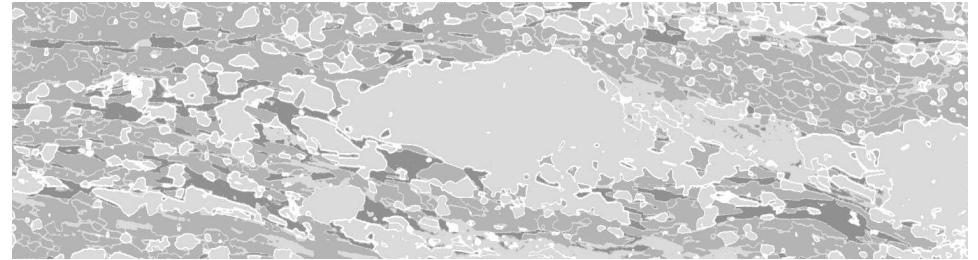
K

Mg

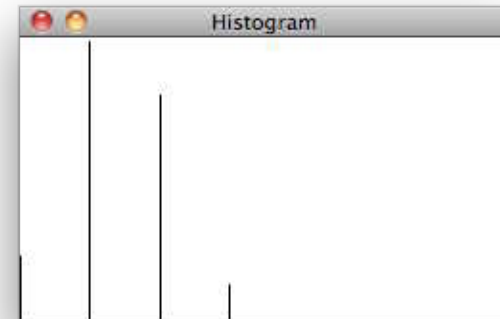
Na

Si

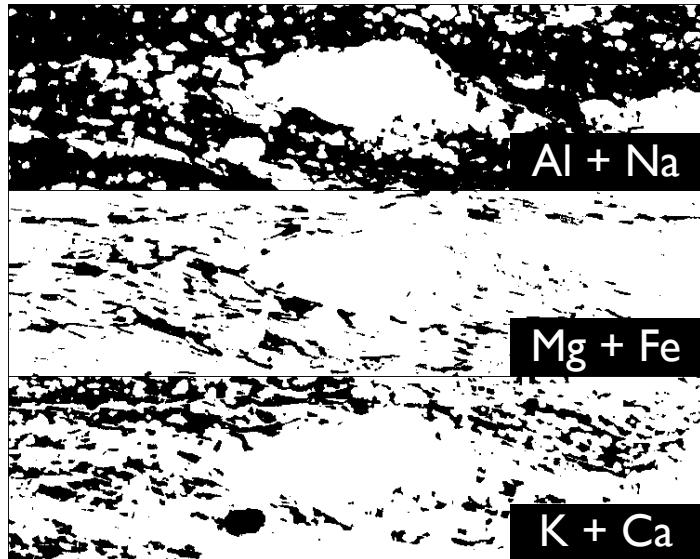
Average



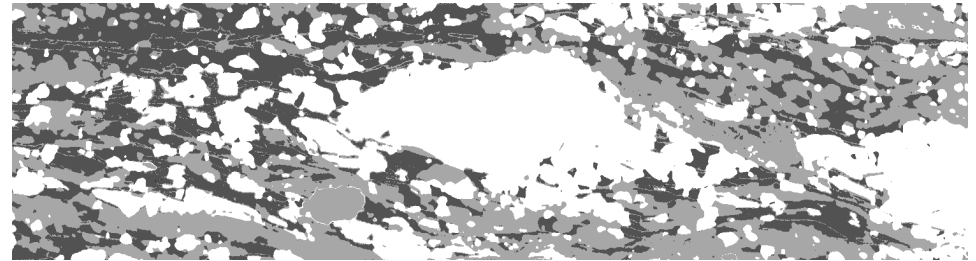
Mineral phases with 1 to 4 different elements



# element pairs

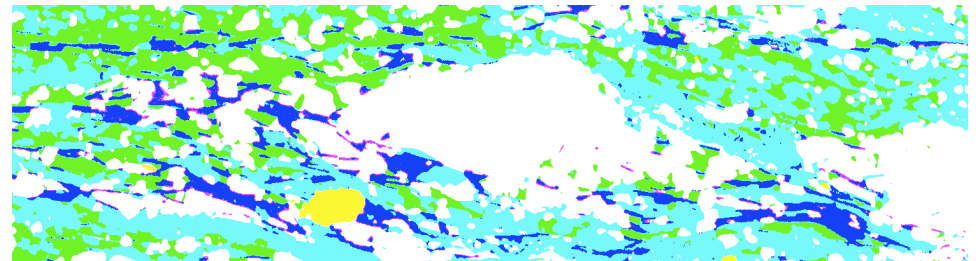


## Average

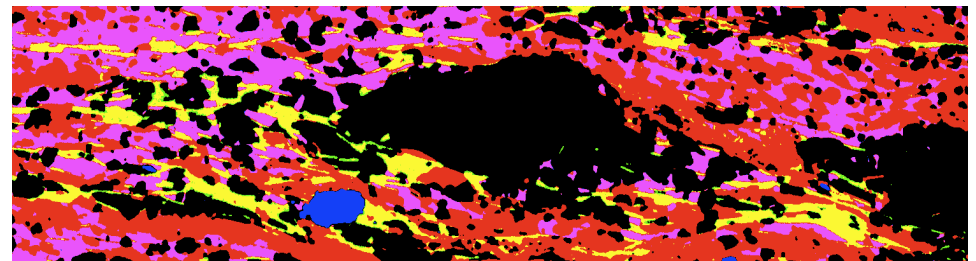


Mineral phases with 1 - 3 pairs of elements, i.e., 1 - 6 different elements

## RGB



## RGB of inverse



# Übung 1 | Verschneideoperationen

Von Element-Verteilungskarten zu Mineralphasen

■ Die Element-Verteilungsbilder aus dem Ordner GP4\_edx öffnen.

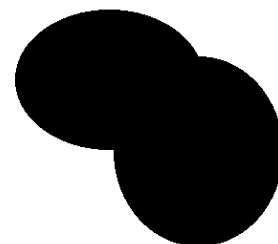
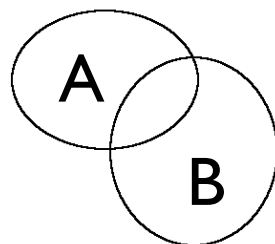
Hohe Counts in den edx Bildern erscheinen hell.

Aus jeweils drei (sinnvoll auszuwählenden) Element-Verteilungsbildern sind Phasenverteilungsbilder herzustellen.

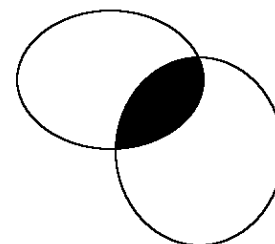
Quarz	$\text{SiO}_2$
Kalifeldspat	$\text{KAlSi}_3\text{O}_8$
Plagioklas	$\text{Na}_{0.8}\text{Ca}_{0.2}\text{Al}_{1.2}\text{Si}_{2.8}\text{O}_8$
Biotit	$\text{K}(\text{Fe},\text{Mg})_3\text{AlSi}_3\text{O}_{10}\text{OH}_2$
Muskovit	$\text{K}(\text{Al})_2\text{AlSi}_3\text{O}_{10}\text{OH}_2$

Stellen Sie die 5 Mineralphasen durch Verschneiden der Elementverteilungsbilder dar.

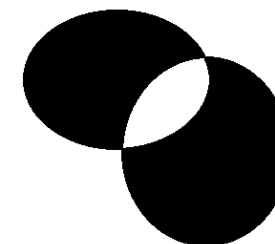
Tipp: Benützen Sie auch Lazy Erode Dilate



A OR B



A AND B



A XOR B

# Übung 12 - phase /grain boundaries

Im segmentierten Bild Phasen- und Korngrenzen finden

- Öffnen Sie das segmentierte Bild Truzzo map scaled im Ordner "Truzzo stack"

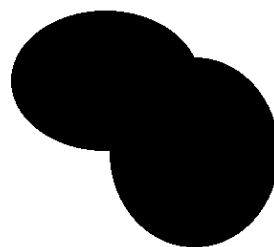
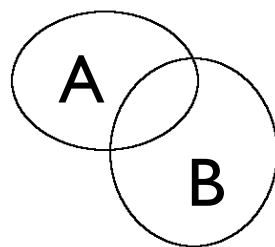
Finden Sie die Korngrenzen.

Welches Verfahren wählen Sie ?

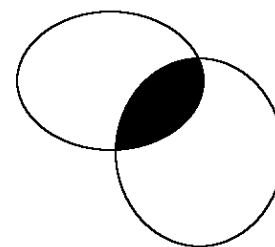
Konvertieren Sie das Bild zu einem Phasen bild.

Wie machen Sie das?

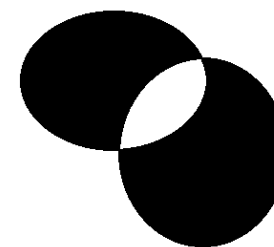
Finden Sie die Phasengrenzen.



A OR B



A AND B



A XOR B



review POP

# recap point operations

I image

LUT:  $f(GV)$  brightness as  $f(\text{index}) = f(GV_{\text{image}})$   
Map:  $f(GV)$   $GV_{\text{screen}}$  as  $f(GV_{\text{image}})$   
transfer function

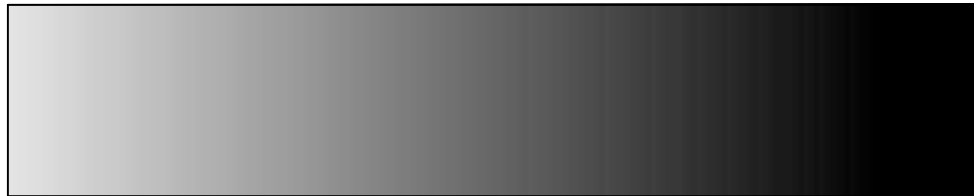
colorLUT:  $R,G,B(GV)$  color as  $f(\text{index})$

Arithmetic: Addition  
Subtraction  
Multiplication  
Division

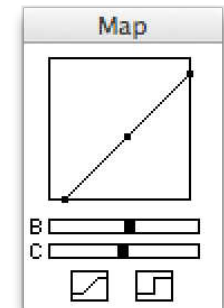
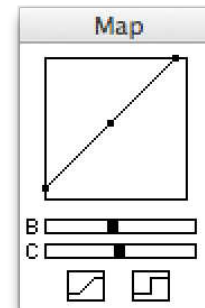
# LUT



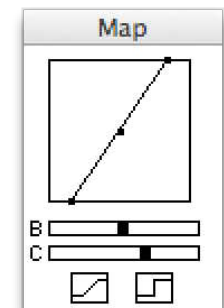
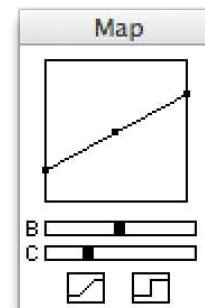
scale



- B



+ B

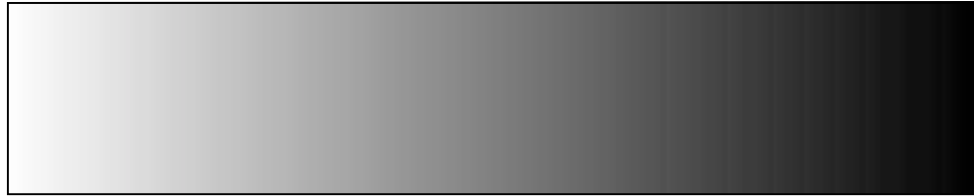


- C

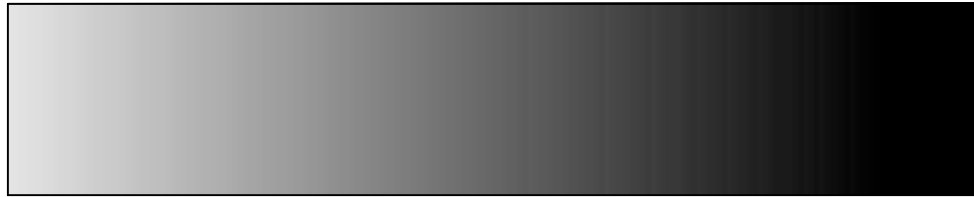


+ C

# Arithmetic



scale



Add 25



Subtract 25



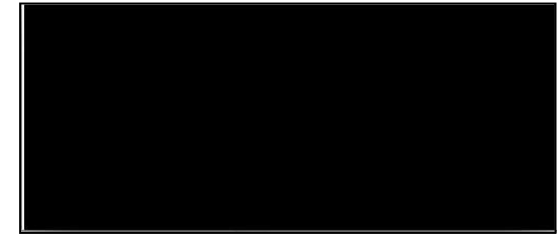
Multiply by 1.25



Divide by 1.25

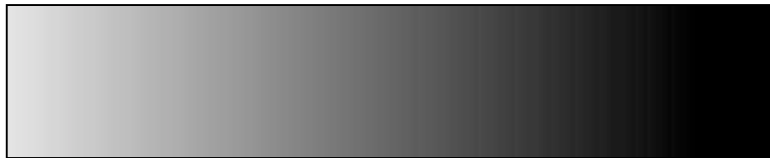


# Arithmetic

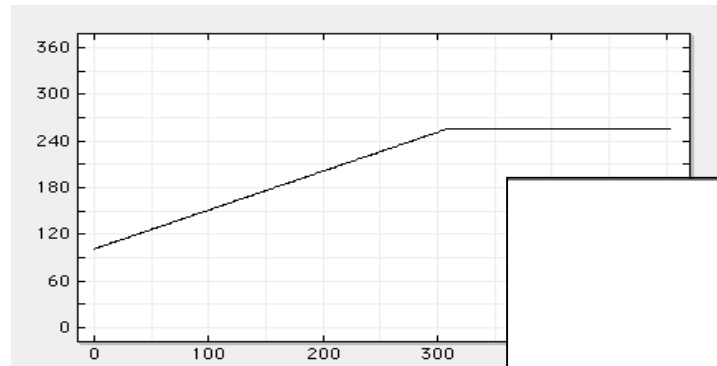


0 histogram 255

## Add 100



Z not calibrated  
GV > 255 set to 255



profile

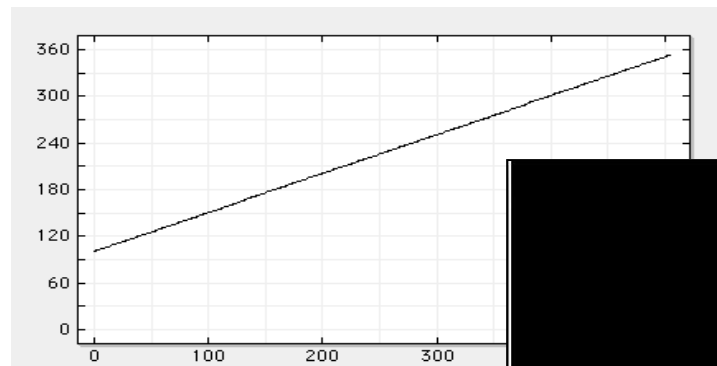


0 histogram 255

## Add 100 real result



Z calibrated from  $GV_{\min}$  to  $GV_{\max}$   
 $0 \rightarrow 100$  and  $255 \rightarrow 355$

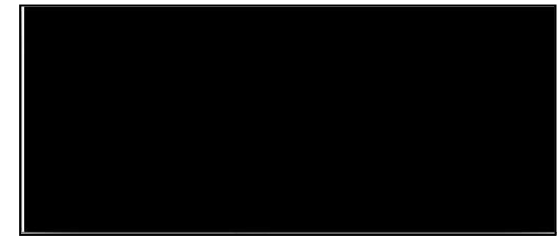


profile



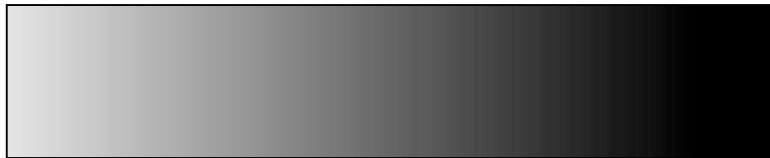
100 histogram 355

# Arithmetic

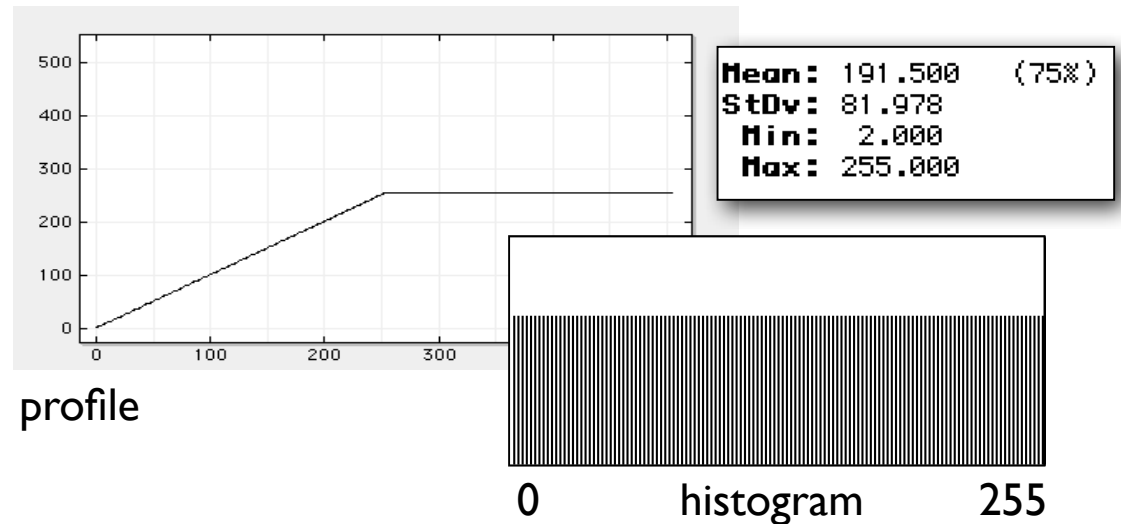


0 histogram 255

Multiply by 2.00



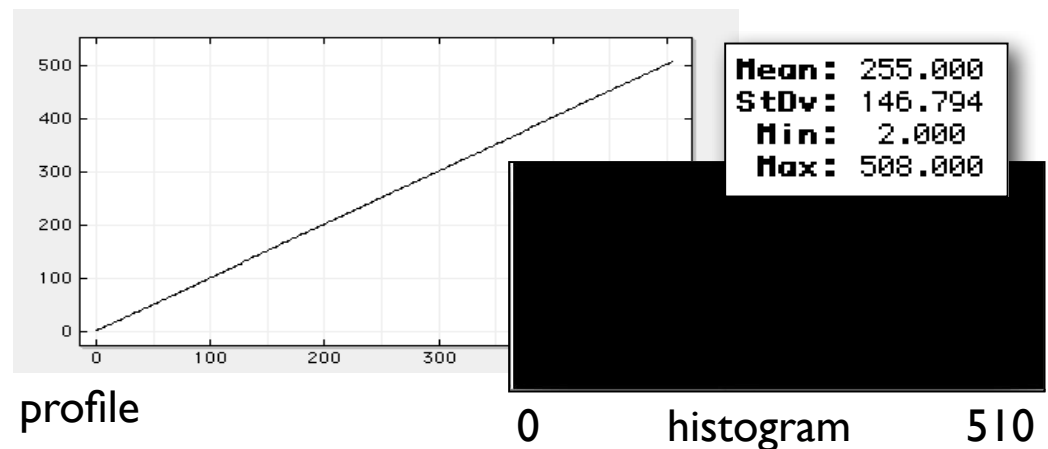
Z not calibrated  
GV>255 set to 255



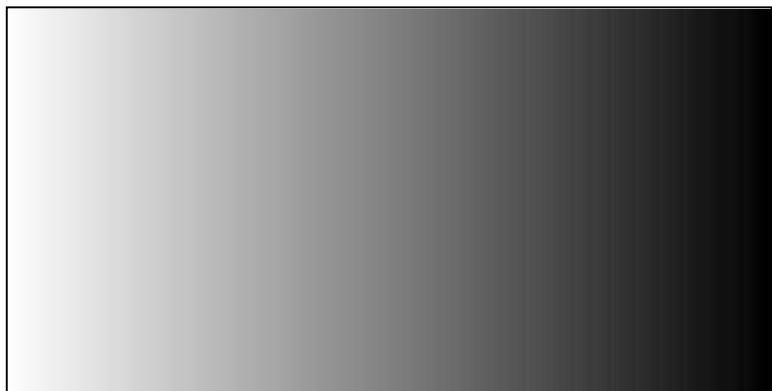
Multiply by 2.00 real result



Z calibrated from  $GV_{\min}$  to  $GV_{\max}$   
 $0 \rightarrow 0$  and  $255 \rightarrow 510$



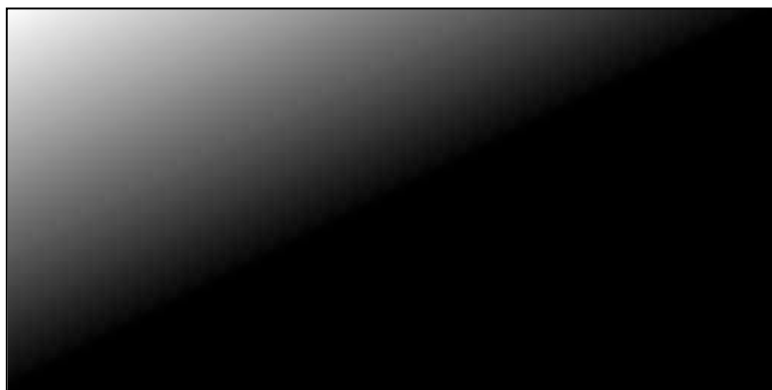
# Adding 2 images



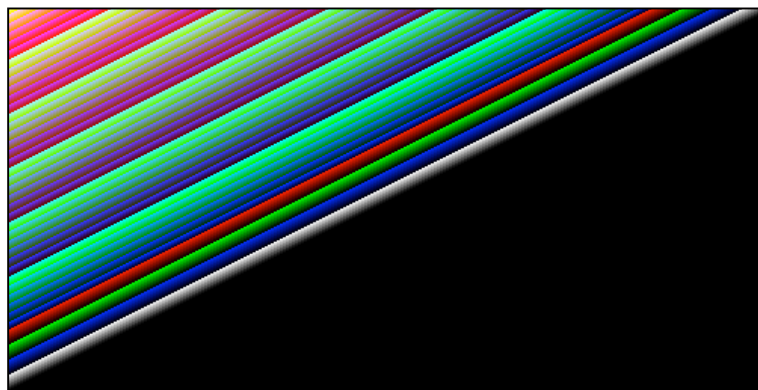
scale 2x1



scale 1x2



(scale 2x1) + (scale 1x2)



(scale 2x1) + (scale 1x2)  
System LUT

# Übung 13 - POP

Arithmetische Operationen durchführen.

- Öffnen scale 508 (warum wohl 508?) im Ordner "POPS on scale"

Addieren Sie 100

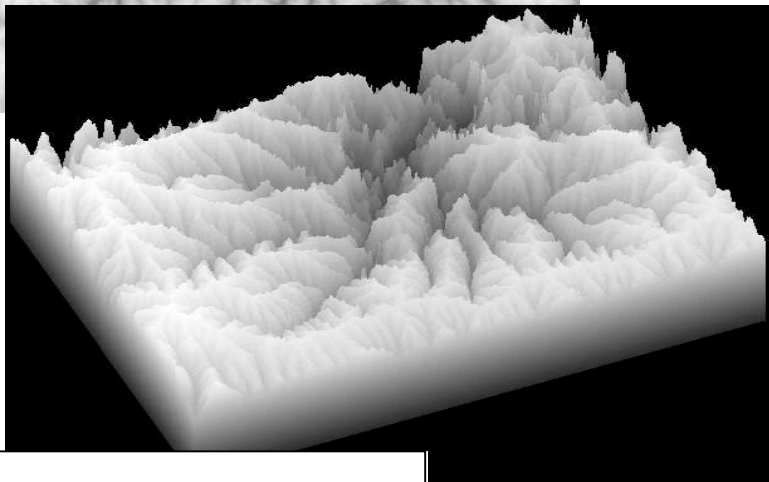
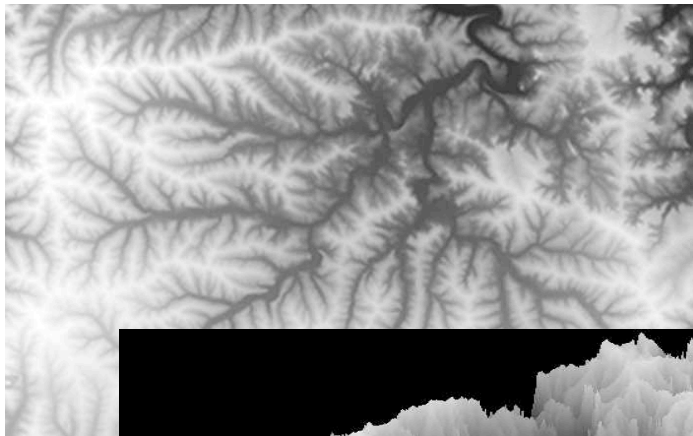
Einmal unkalibriert - einmal kalibriert (Real Result)

Multiplizieren Sie mit 2

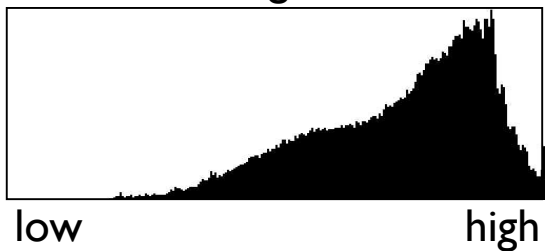
Einmal unkalibriert - einmal kalibriert (Real Result)



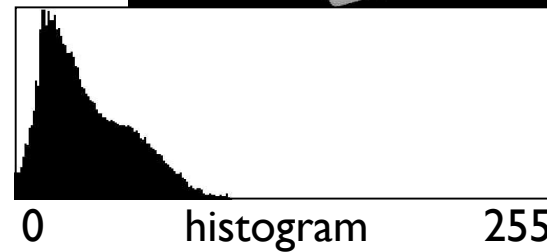
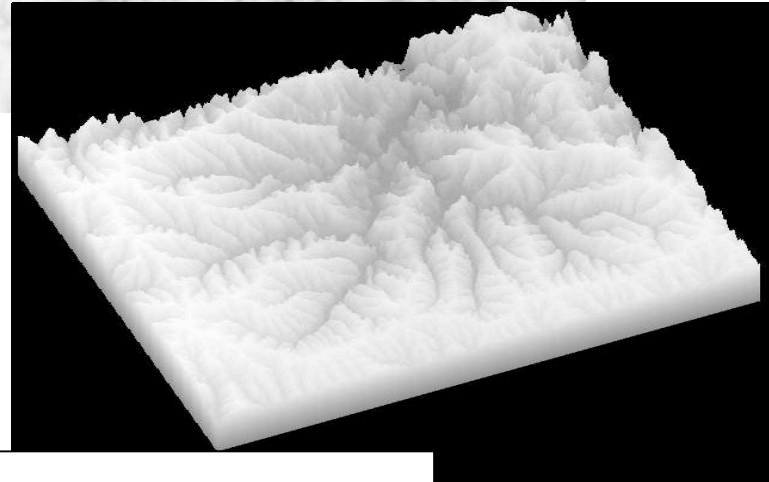
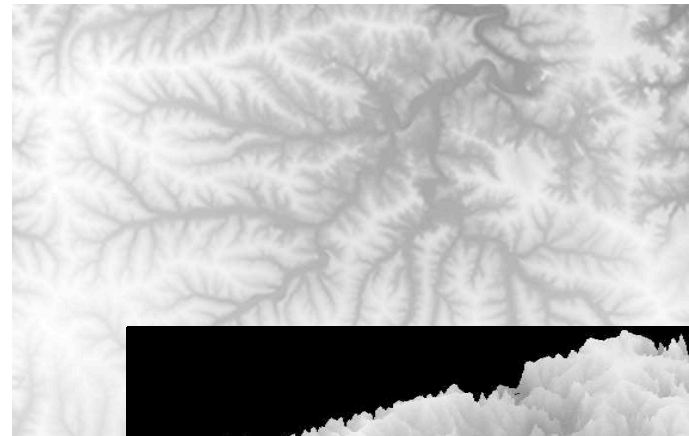
# operate on Z values in entire matrix



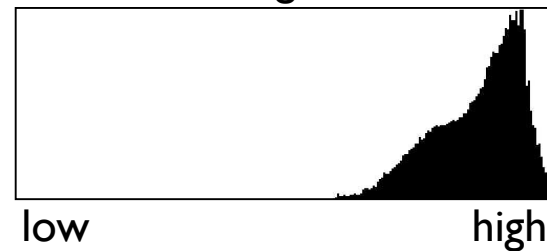
grey values



altitude

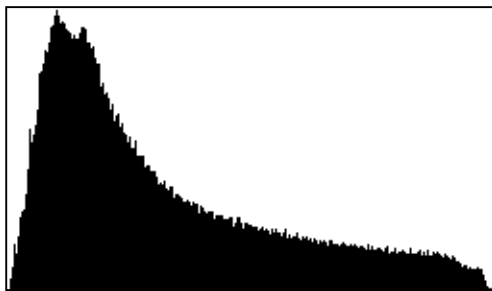
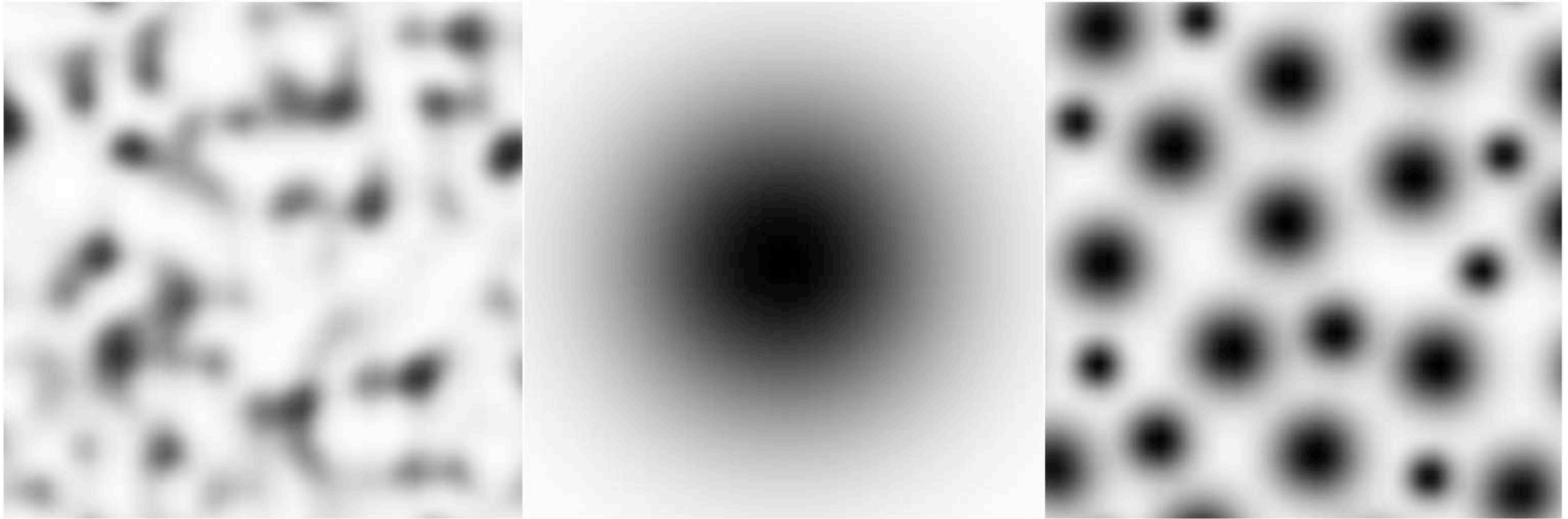


grey values



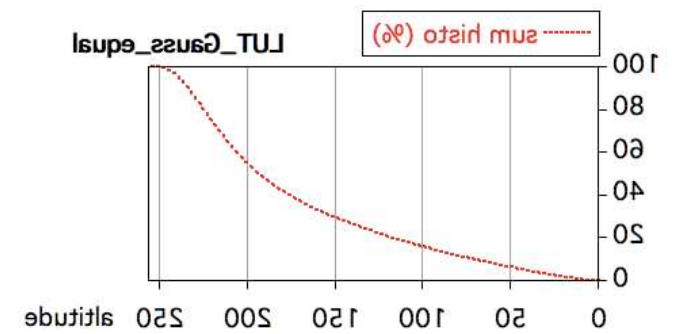
altitude

# Hypsometrisches Integral

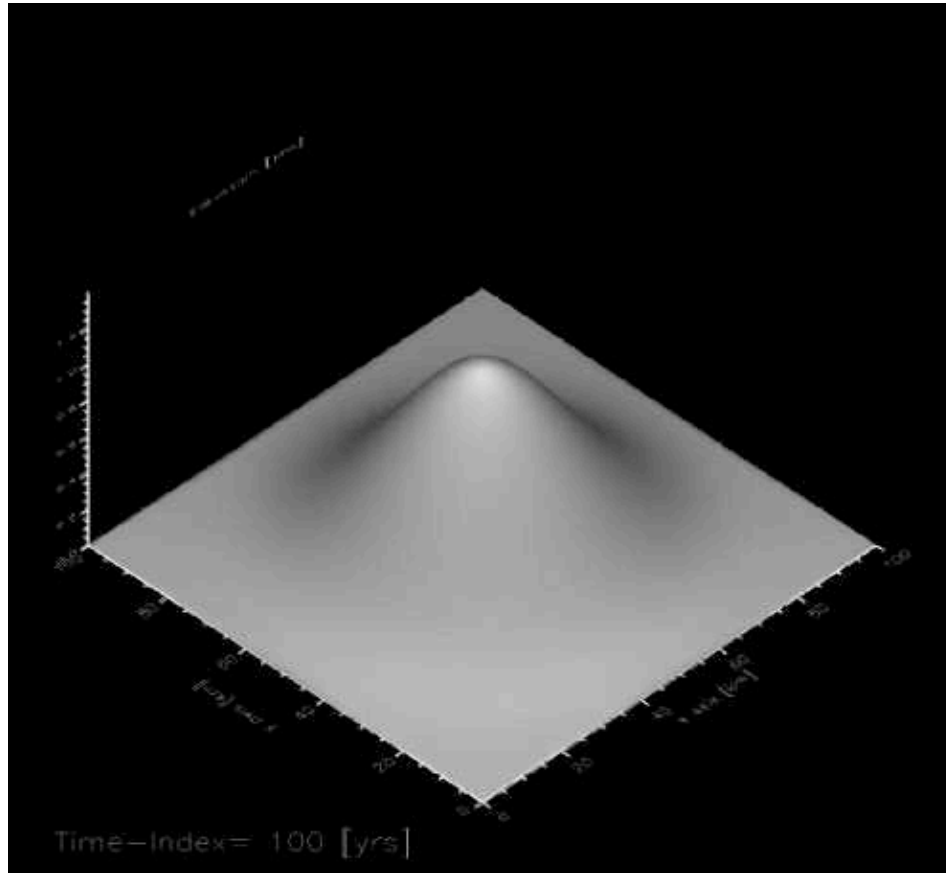


low

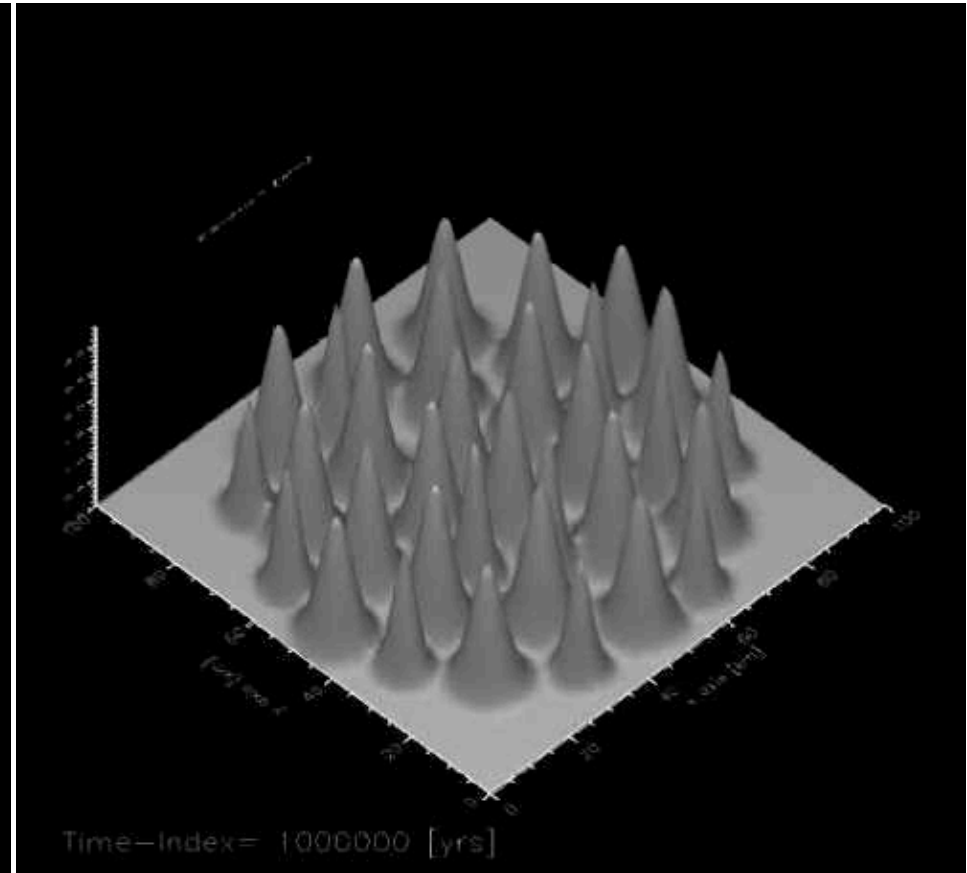
high



# Erosion



dauert 4.9 Ma



dauert 2.1 Ma

# Übung 14 - Digital elevation models (DEM)

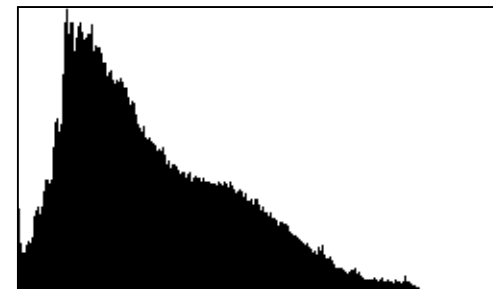
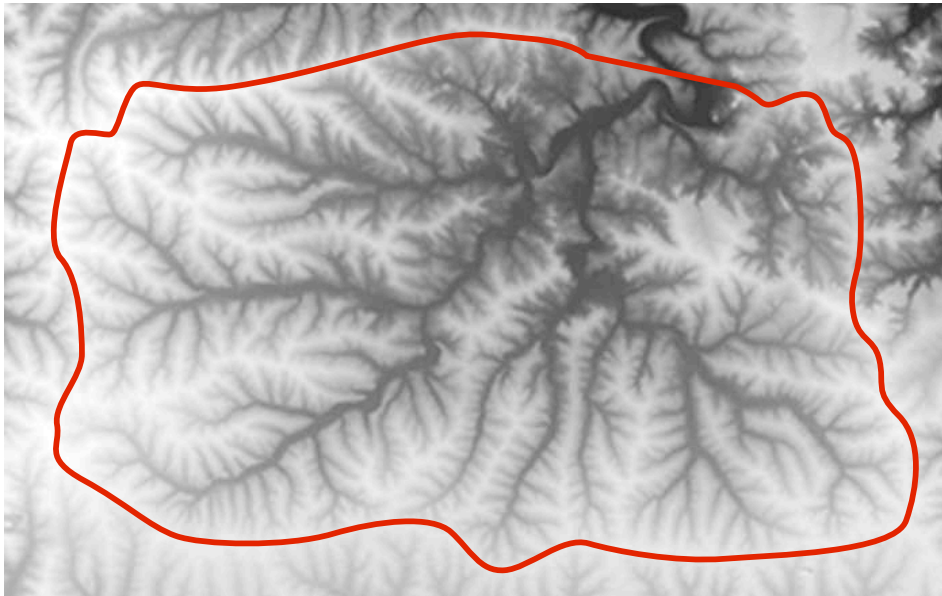
Bedeutung des hypsometrischen Integrals erkennen.

- Öffnen das Bild / das Höhenmodell river im Ordner "DEMs"

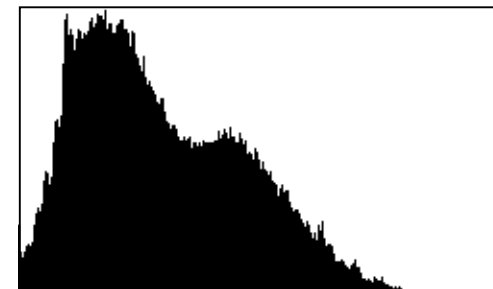
Das Bild ist weder skaliert noch kalibriert, d.h. Länge und Breite ist in Pixel angegeben, Höhe ist in Grauwerten (0-255)

Wählen Sie ein Einzugsgebiet aus - stellen Sie das Histogramm her.

Exportieren Sie die Histogramm-Daten und berechnen Sie das hypsometrische Integral (Summenkurve)



ganzes Bild



Einzugsgebiet



# Übung 15 - Unsharp mask

Die Funktionsweise einer Unsharp mask kennen lernen.

- Öffnen das Bild parrot\_head im Ordner "parrot"

Versuchen Sie es durch Unsharp masking (mit parrothead\_Gauss\_15x15) zu schärfen.

Wie gehen Sie vor ?



parrothead



parrothead -  
(parrothead Gaussian 15x15)



parrothead  $\otimes$  Gaussian 15x15

# DBA 2014


## session 6

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
→ URZ - Universitätsrechenzentrum  
→ VIA - Vorlesungsverzeichnis  
→ PERSSEARCH - Personensuche

HOME Contact Studium Geowissenschaften Lehrveranstaltungen Vorträge und Links Strukturgeologie  
Rock Information Projects & Software Workshops Textbook DDM Macros Image Macros Image Analysis

LEHRVERANSTALTUNGEN



...l'œil n'est pas "L'appel des cimes" de René Magritte...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehalle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageEXM bzw. image kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageEXM software (Mac/CSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Estimation (2-D -> 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formalanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software Image EXM, bzw. image (alle public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungbestellung möglich)
- Harterter, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET** earth.unibas.ch  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

TICMISO GEOMAGING

→ TICMISO CRISTAL DYNAMICS HOMEPAGE (English)  
→ TICMISO GEOLOGY HOMEPAGE (Norwegian)  
→ TICMISO UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>

# Semesterfahrplan: Fahrplanänderung

			Freitag CR 14-17	Montag CR 14-17
	Thema	Doz.	Gruppe A	Gruppe B
1	Images for image analysis - intro: ImageSXM	RH	19-Sep-2014	22-Sep-2014
2	Digital Images - Pixels - LUTs	RH	26-Sep-2014	29-Sep-2014
3	Explore / pre-process digital images - intro: imageJ	RK	3-Oct-2014	6-Oct-2014
4	POP segmentation - post-processing	RK	10-Oct-2014	13-Oct-2014
5	Mathem./Punkt-Operationen Verschneide-Operationen	RH	17-Oct-2014	
		RH		27-Oct-2014
	(fällt aus)			
			nur Freitag CR 14-17	
6	Filtern - Kantendetektion - NOP segmentation	RH	7-Nov-2014	
7	Analyze: segments - best-fit ellipses - property maps	RH	14-Nov-2014	
8	Fourier-Transformationen Autokorrelation	RH	21-Nov-2014	
	(Dies Academicus)			
9	Korngrößen-Analyse Stereologie - Kontaktflächen	RH	5-Dec-2014	
Test			12-Dec-2014	

pro Nachmittag: 1. Teil: Vorlesung (Einführung in das Thema) - 2. Teil: Übungen  
Besprechung der Übungen am Anfang der nächsten Vorlesung

# Übung 15 - Unsharp mask

Die Funktionsweise einer Unsharp mask kennen lernen.

- Öffnen das Bild parrot\_head im Ordner "parrot"

Versuchen Sie es durch Unsharp masking (mit parrothead\_Gauss\_15x15) zu schärfen.

Wie gehen Sie vor ?



parrothead



parrothead -  
(parrothead Gaussian 15x15)



parrothead  $\otimes$  Gaussian 15x15



# neighbourhood operations (NOP)

# 3 x 3 neighborhood

$i-1 / j-1$	$i / j-1$	$i+1 / j-1$
$i-1 / j$	$i / j$	$i+1 / j$
$i-1 / j+1$	$i / j+1$	$i+1 / j+1$

# introductory example: moving average



166	89	72	89	79	82	139	84	22	44	99	131	156	183	193	168	
102	49	39	51	62	70	72	31	22	56	124	161	180	205	212	190	
70	34	31	62	65	107	114	70	56	72	114	143	180	205	207	171	
44	29	24	44	124	92	67	70	56	46	60	151	226	188	141	99	
31	29	7	14	84	39	14	27	24	44	114	126	236	219	107	67	
24	39	22	9	12	27	19	29	19	54	109	89	183	255	193	97	
24	27	24	17	17	39	75	102	82	94	126	141	168	231	231	178	
22	22	27	26	18	28	114	121	121	141	168	168	183	207	200	177	
19	101	86	64	65	72	84	79	61	43	61	102	141	169	188	191	190
17	85	72	57	61	74	87	85	67	50	67	104	143	171	191	192	190
14	54	46	40	55	75	85	77	62	53	67	103	148	182	193	179	170
12	39	33	30	50	70	78	66	55	51	65	96	150	186	189	156	132
14	32	27	24	37	49	53	42	36	41	58	88	143	185	194	151	117
27	29	25	20	22	28	36	41	43	52	74	99	143	183	202	175	145
29	26	25	24	20	22	39	61	75	84	101	121	149	181	206	195	177
24	22	24	28	26	26	43	70	96	106	115	132	156	183	196	187	176
	21	27	35	33	27	42	76	106	112	110	120	140	162	168	156	146
	20	26	32	29	22	37	75	101	104	91	93	108	126	132	124	116
	18	22	25	22	19	38	80	102	103	88	84	89	90	97	98	96
	16	16	18	23	34	58	96	114	120	112	108	104	89	84	82	82
	20	24	37	57	78	98	125	139	147	145	143	134	102	75	59	57
	29	44	75	110	134	145	159	169	176	176	169	152	108	65	36	30
	34	56	98	140	164	168	170	173	178	178	164	139	90	46	14	8
	35	62	108	151	172	172	168	170	175	175	155	124	75	35	8	4

# Neighbourhood operations

example: moving average

30	25	23
25	10	15
13	1	5

 · 

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

 = 

30	25	23
25	10	15
13	1	5

 · 1/9 

1	1	1
1	1	1
1	1	1

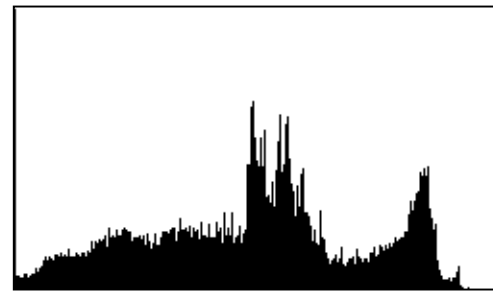
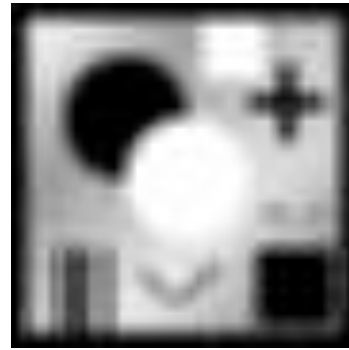
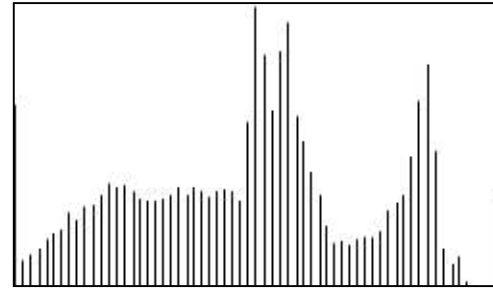
$$= 1/9 \cdot [30 + 25 + \dots + 5] = 15$$



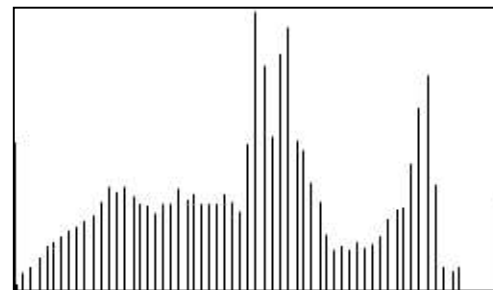
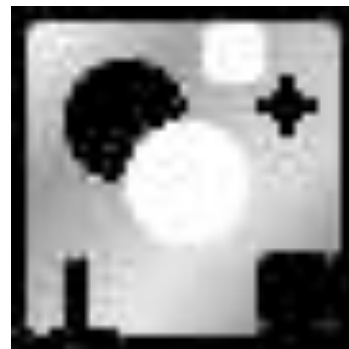


# averaging filters

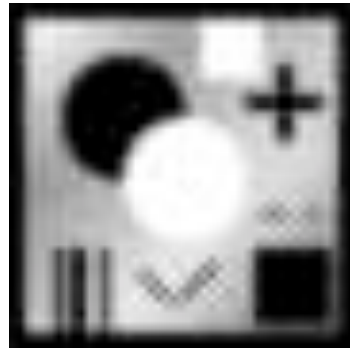
# moving average




≠ median

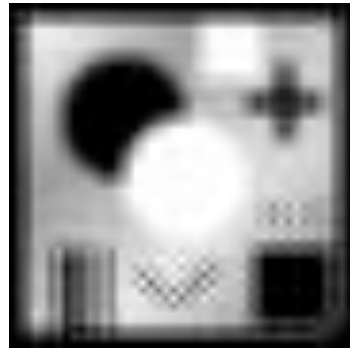


# moving average



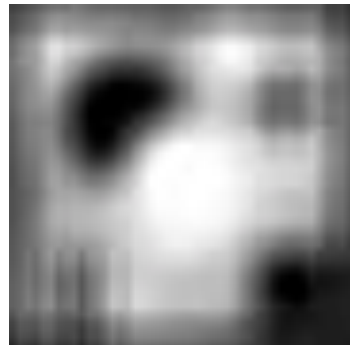
influence of shape

0	1	0
1	1	1
0	1	0



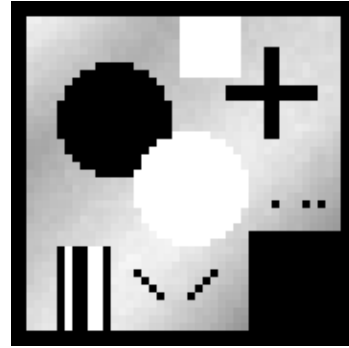
1	0	1
0	1	0
1	0	1

influence of size

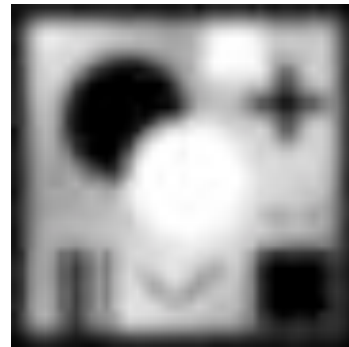


1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1

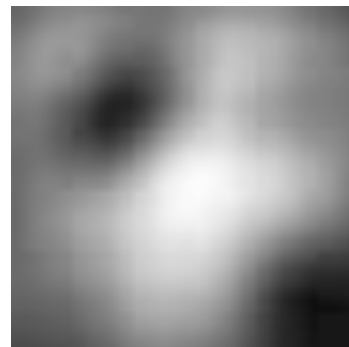
# Gaussian



(5x5)



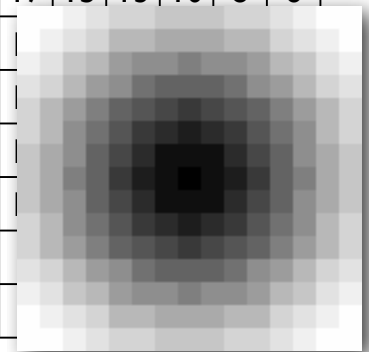
(15x15)



$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

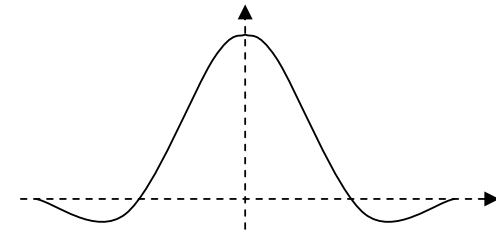
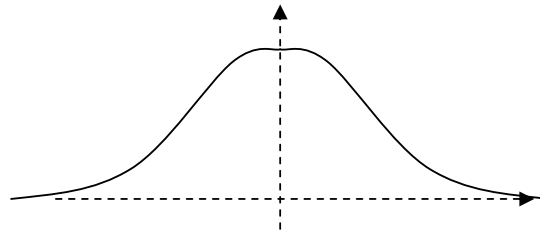
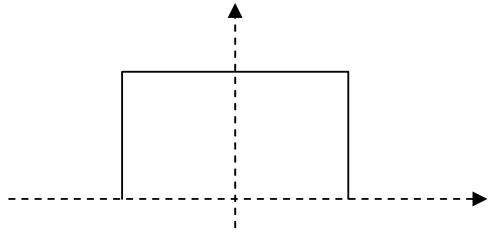
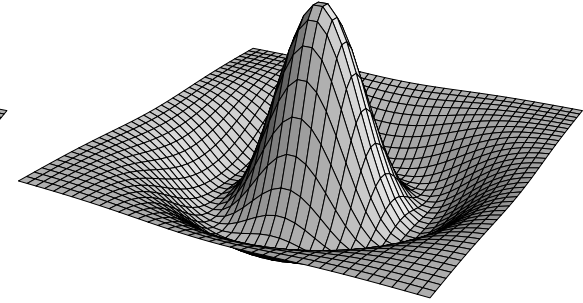
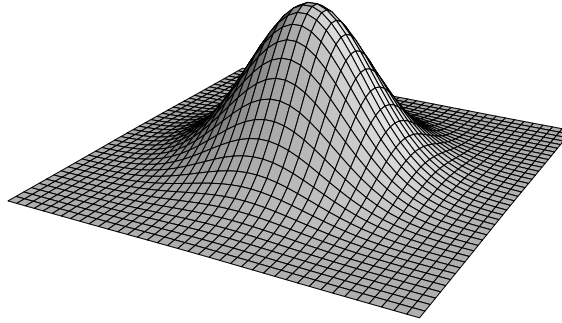
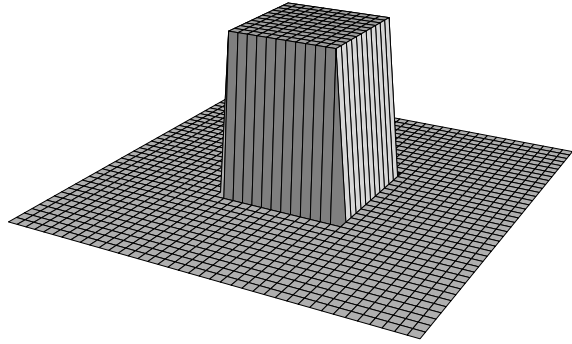
1	1	2	1	1
1	2	4	2	1
2	4	8	4	2
1	2	4	2	1
1	1	2	1	1

2	2	3	4	5	5	6	6	6	5	5	4	3	2	2
2	3	4	5	7	7	8	8	8	7	7	5	4	3	2
3	4	6	7	9	10	10	11	10	10	9	7	6	4	3
4	5	7	9	10	12	13	13	13	12	10	9	7	5	4
5	7	9	11	13	14	15	16	15	14	13	11	9	7	5
5	7	10	12	14	16	17	18	17	16	14	12	10	7	5
6	8	10	13	15	17	19	19	19	17	15	13	10	8	6
6	8	11	13	16	18	19	20	19	18	16	13	11	8	6
6	8	10	13	15	17	19	19	19	17	15	13	10	8	6
5	7	10	12	14	16	17	18	17	16	14	12	10	8	6
5	7	9	11	13	14	15	16	15	14	12	10	8	6	5
4	5	7	9	10	12	13	13	13	12	10	8	6	5	4
3	4	6	7	9	10	10	11	10	10	9	7	6	5	4
2	3	4	5	7	7	8	8	8	7	7	5	4	3	2
2	2	3	4	5	5	6	6	6	5	5	4	3	2	2





# linear filters



0	0	0	0	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	0	0	0	0

0	1	2	1	0
1	3	5	3	1
2	5	9	5	2
1	3	5	3	1
0	1	2	1	0

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

# Übung 16 - Filtern

Filtermatrizen kennenlernen

■ Öffnen das Bild Parrot\_P\_64.tif bzw. parrothead.tif (session 6). Unterschied ?

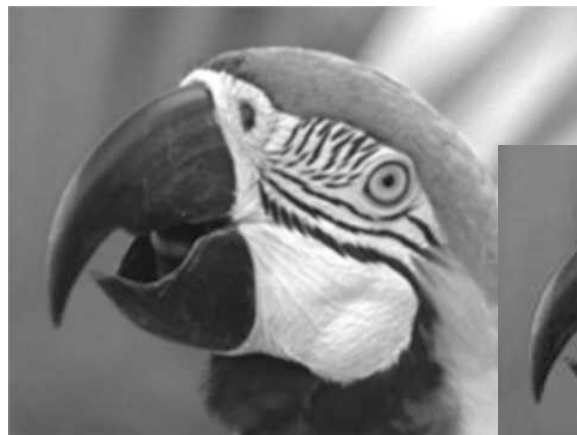
Öffnen Sie ein Textfenster und schreiben sie einen 5x5 Boxfilter.

Wenden sie den Filter auf das Bild an (Kopie verwenden). Histogramm ?

Schreiben Sie weitere averaging filter verschiedener Grösse und Form und wenden Sie sie auf das Bild an (Kopie verwenden).

Öffnen Sie Gauss (15x15) einmal als Textfenster, einmal als Bild. Führen Sie die entsprechende Gaussfilterung durch.

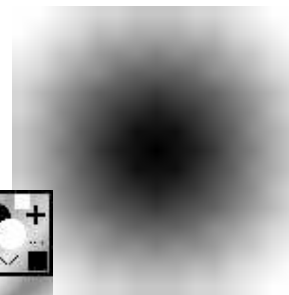
Entwerfen Sie einen kleinen Filter als Bild - exportieren Sie ihn als Text und wenden Sie ihn auf das Bild (approthead) an.



parrothead.tif



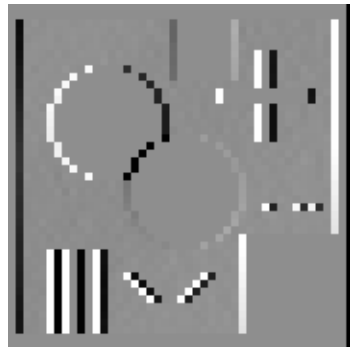
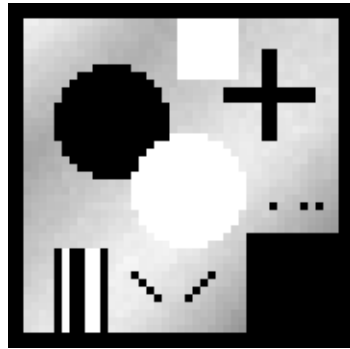
Parrot\_P\_64.tif



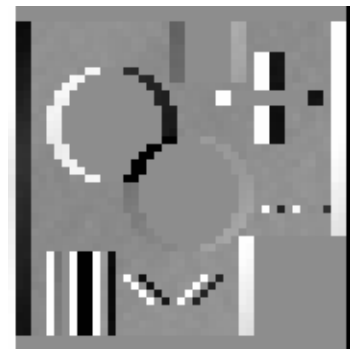
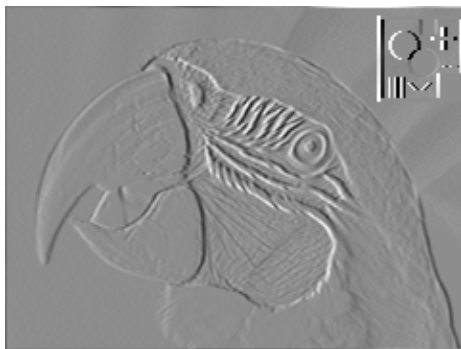
2	2	3	4	5	5	6	6	6	5	5	4	3	2	2
2	3	4	5	7	7	8	8	8	7	7	5	4	3	2
3	4	6	7	9	10	10	11	10	10	9	7	6	4	3
4	5	7	9	10	12	13	13	13	12	10	9	7	5	4
5	7	9	11	13	14	15	16	15	14	13	11	9	7	5
5	7	10	12	14	16	17	18	17	16	14	12	10	7	5
6	8	10	13	15	17	19	19	19	17	15	13	10	8	6
6	8	11	13	16	18	19	20	19	18	16	13	11	8	6
6	8	10	13	15	17	19	19	19	17	15	13	10	8	6
5	7	10	12	14	16	17	18	17	16	14	12	10	7	5
5	7	9	11	13	14	15	16	15	14	13	11	9	7	5
4	5	7	9	10	12	13	13	13	12	10	9	7	5	4
3	4	6	7	9	10	10	11	10	10	9	7	6	4	3
2	3	4	5	7	7	8	8	8	7	7	5	4	3	2
2	2	3	4	5	5	6	6	6	5	5	4	3	2	2

# gradient filters

# horizontal difference - separation



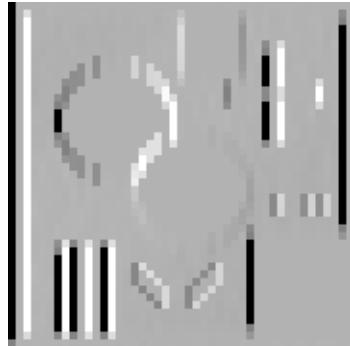
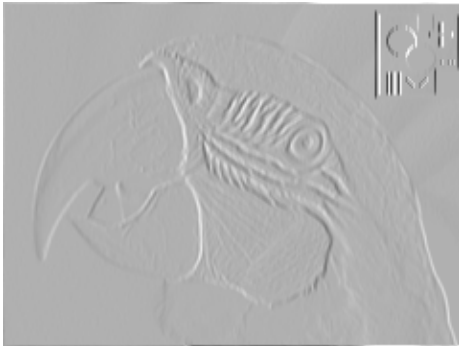
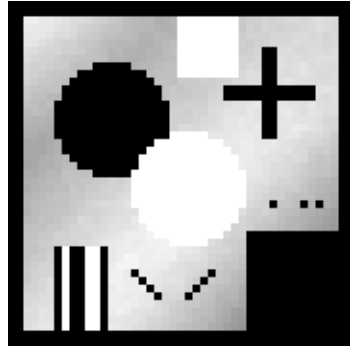
0	0	0
0	1	-1
0	0	0



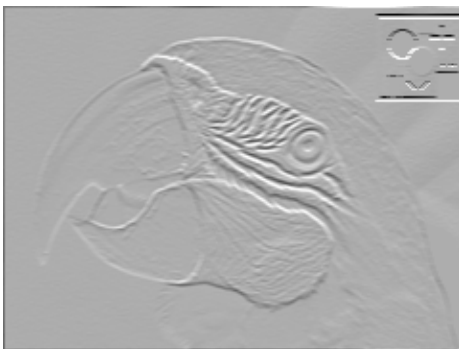
0	0	0
1	0	-1
0	0	0



# horizontal difference - direction

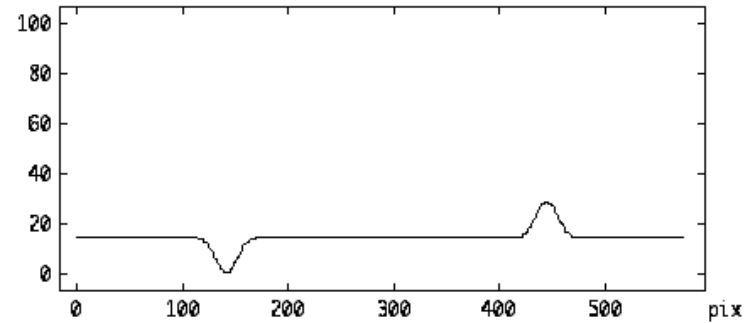
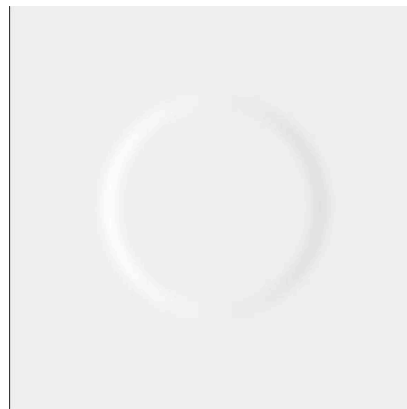
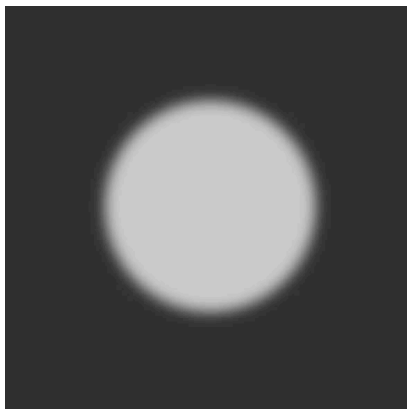
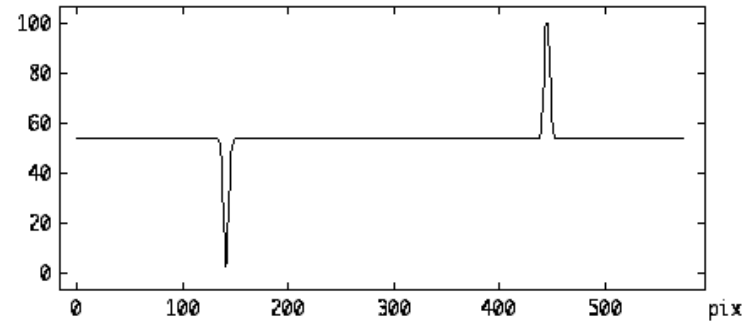
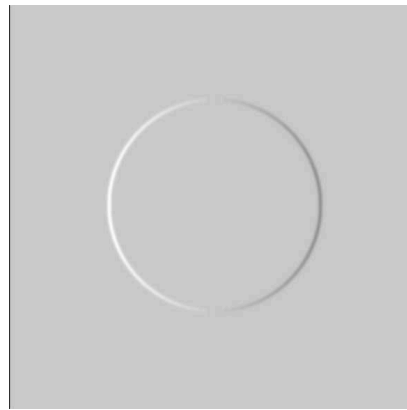
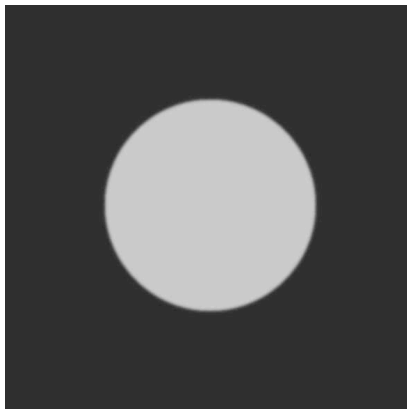


-1	0	1
-1	0	1
-1	0	1

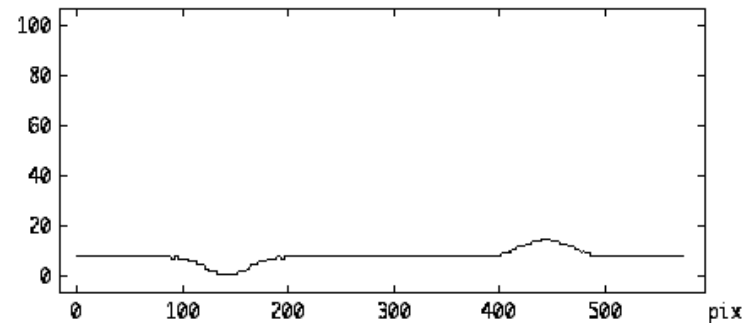
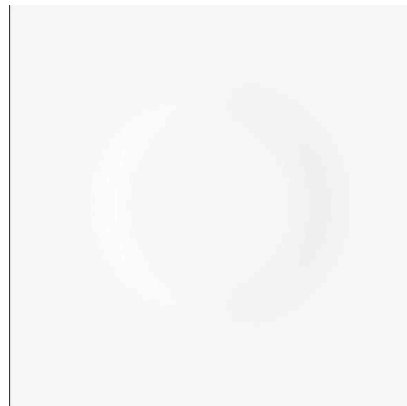
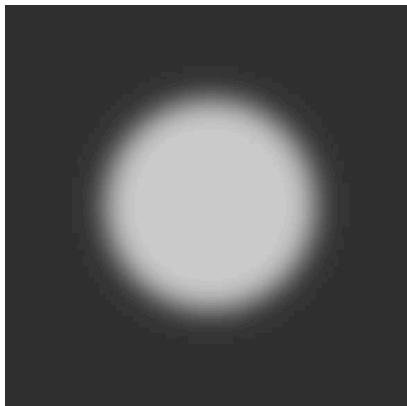


-1	-1	-1
0	0	0
1	1	1

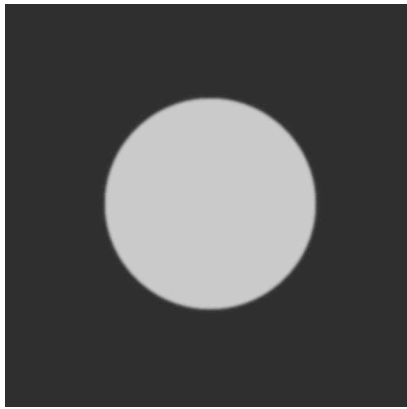
# horizontal difference - slope



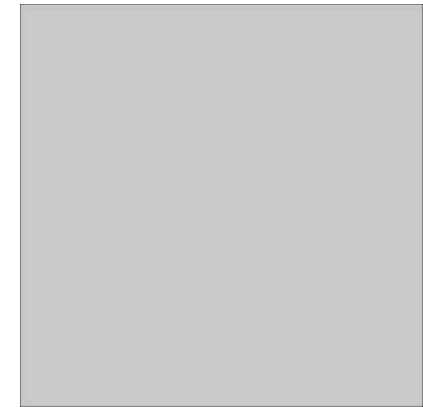
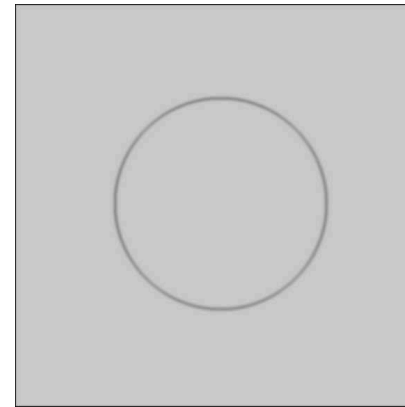
0	0	0
-0.5	0	0.5
0	0	0



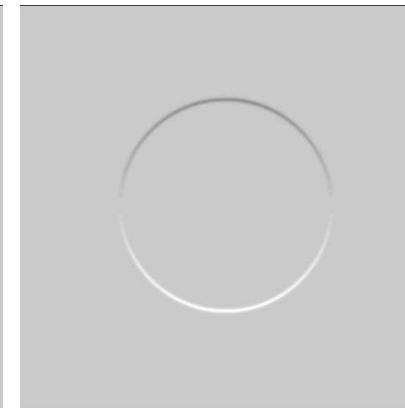
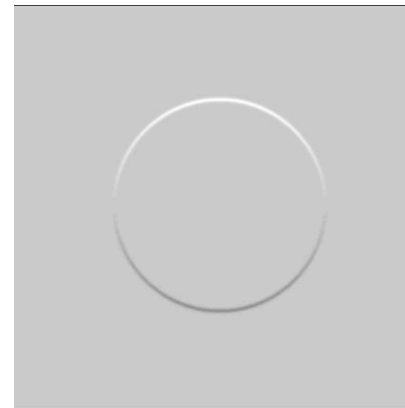
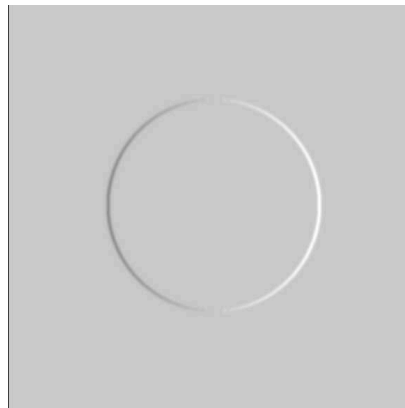
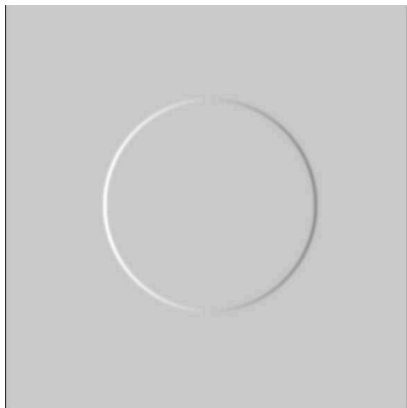
# gradient filters



maximum of 4  
↑



(average of 4)



0	0	0
-0.5	0	0.5
0	0	0

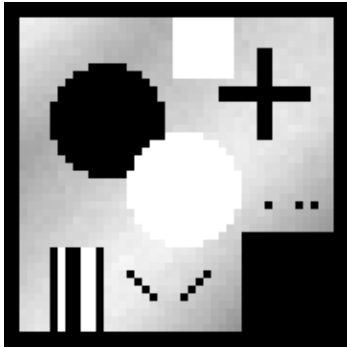
0	0	0
0.5	0	-0.5
0	0	0

0	-0.5	0
0	0	0
0	0.5	0

0	0.5	0
0	0	0
0	-0.5	0

# Sobel operator

(1st derivative)

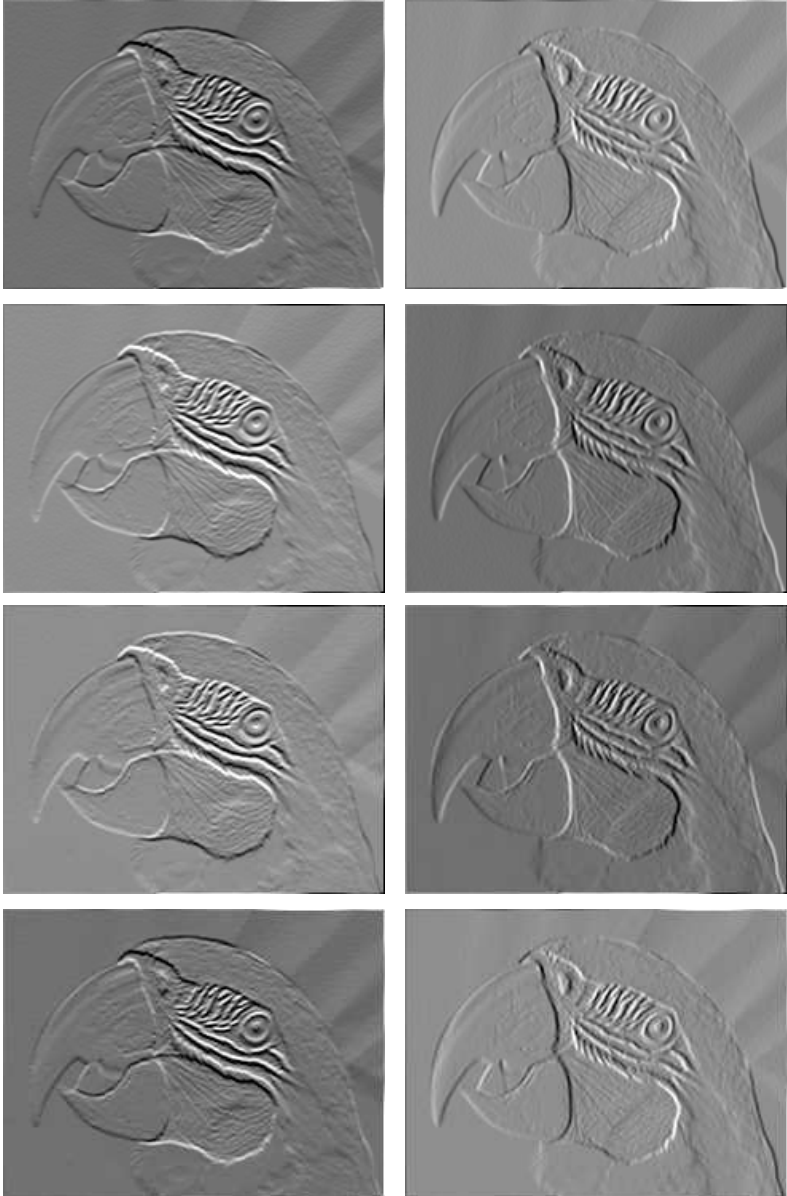
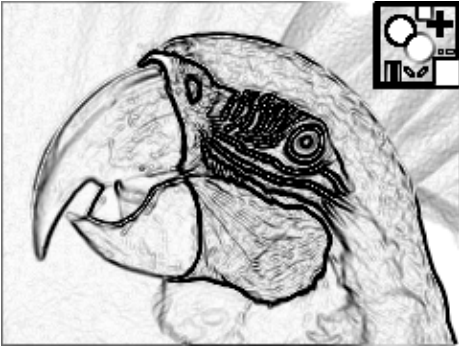


1	2	1	1	0	-1	-1	-2	-1	-1	0	1
0	0	0	2	0	-2	0	0	0	-2	0	2
-1	-2	-1	1	0	-1	1	2	1	-1	0	1

-2	-1	0	0	1	2	2	1	0	0	-1	-2
-1	0	1	-1	0	1	1	0	-1	1	0	-1
0	1	2	-2	-1	0	0	-1	-2	2	1	0

maximum of 8 directions

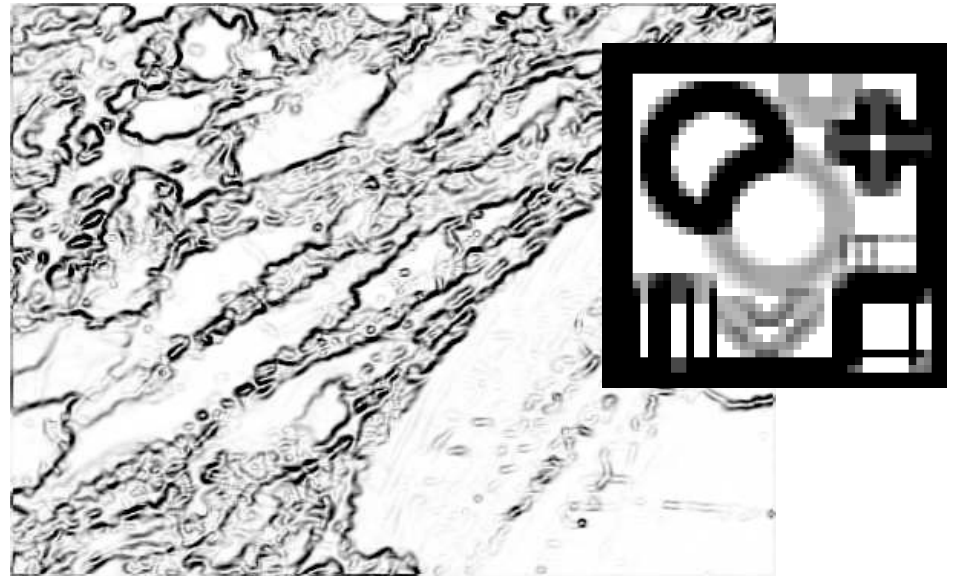




Sobel 3x3 (ImageSXM)



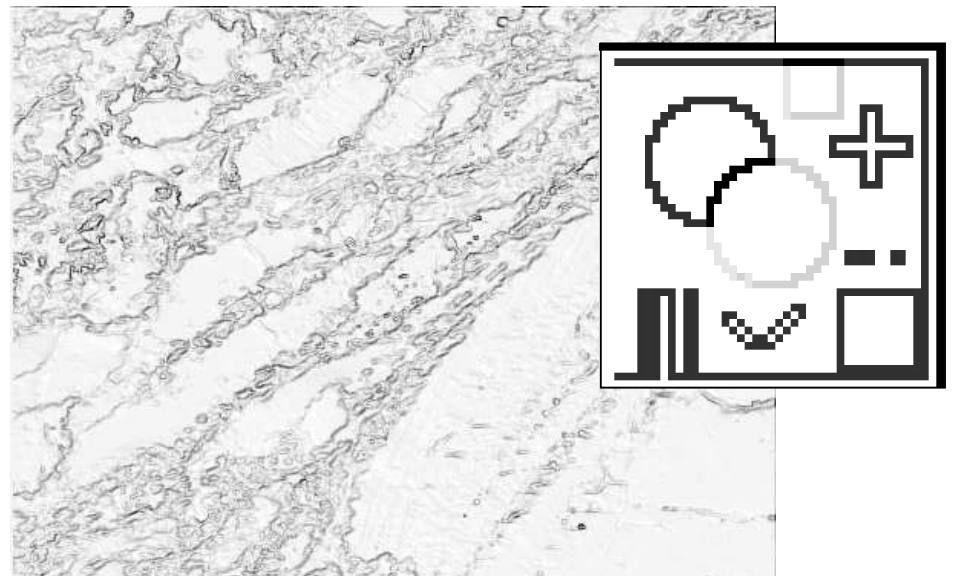
Find edges 5x5 (ImageSXM)



'hand-made' Sobel



Roberts Cross



# Übung 17 - Filtern

## Process

Die Kantendetektion (Sobel) kann auf Image SXM durch 8 Faltungen (convolutions) mit untenstehendem kernel in 8 mögliche Richtungen "nachgebaut" werden.

$$\begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix}$$

Das maximum dieser 8 Bilder ergibt die Sobel-filterung



Verfahren an einem Bild ausprobieren und mit "Find edges" im menu "Process" vergleichen

# Kantendetektoren



Original



Roberts



Prewitt



Sobel



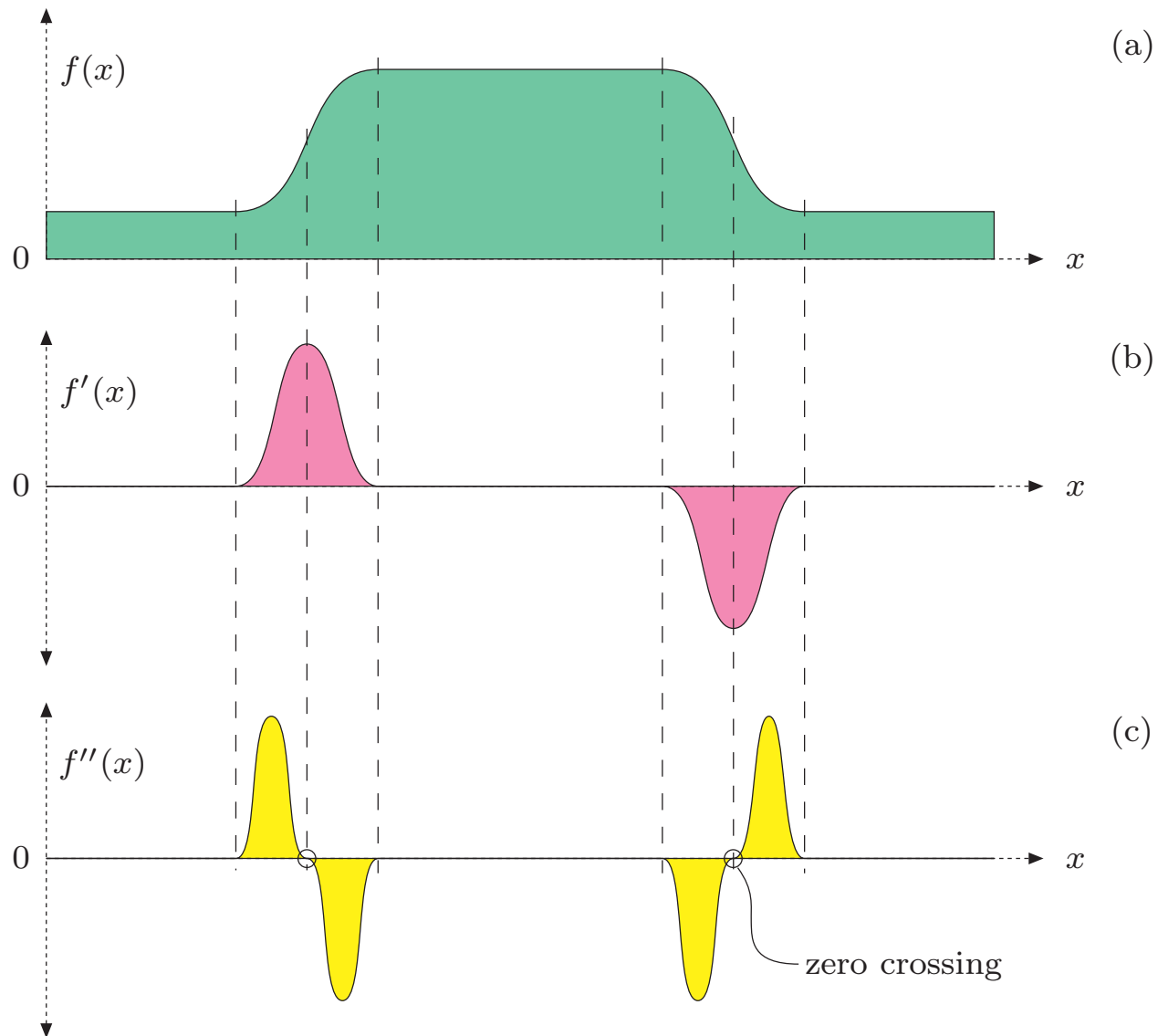
Laplacian of Gaussian



Canny ( $\sigma = 1.0$ )

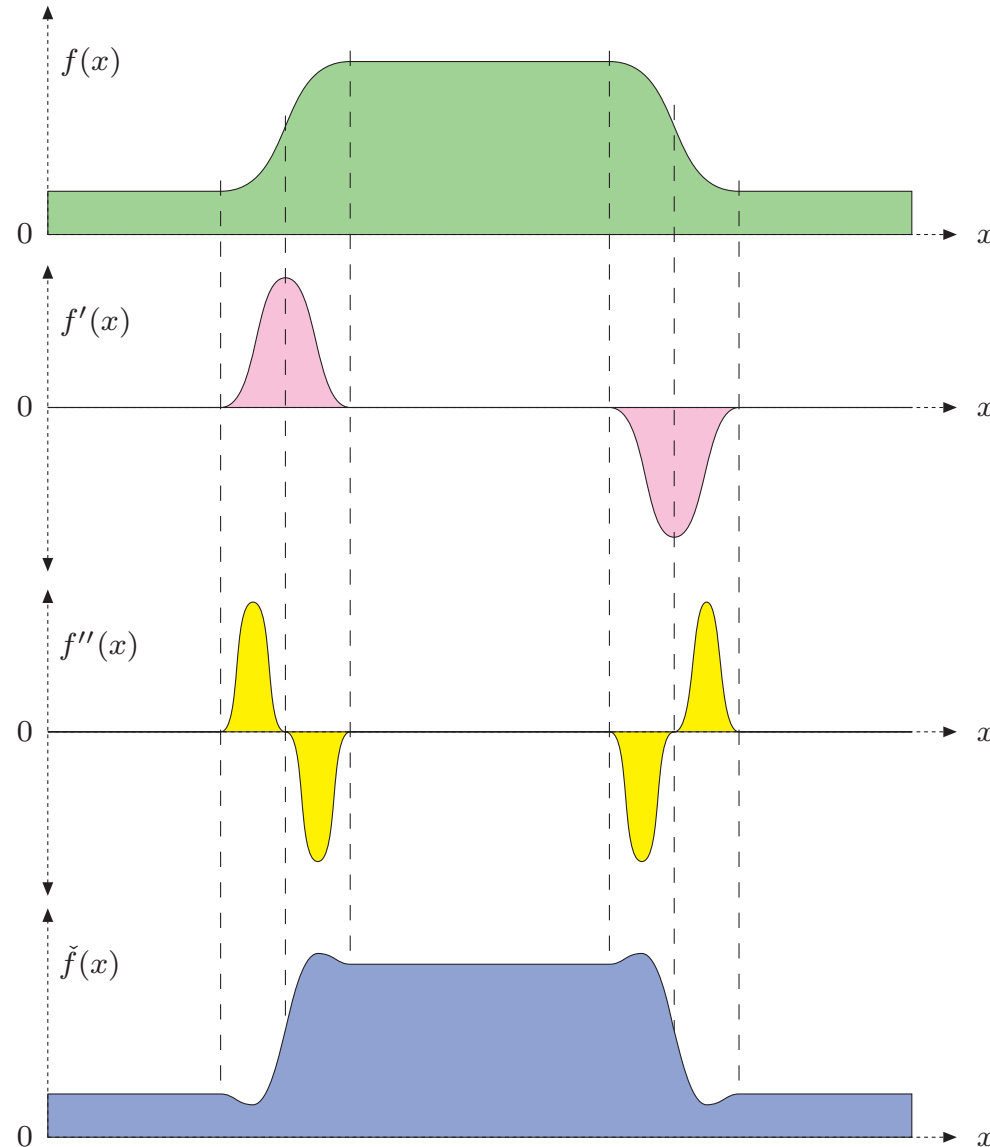
# Laplace filters

# I. und 2. Ableitung - Kantendetektion





# 1. und 2. Ableitung - Schärfen



image

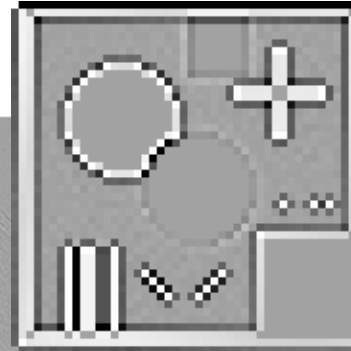
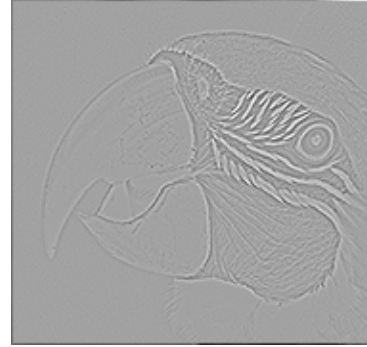
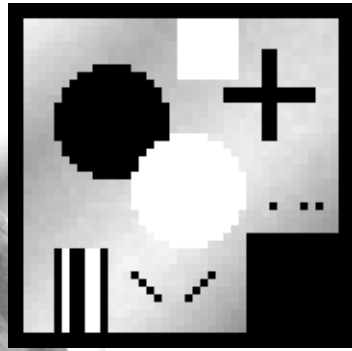
gradient filter  
edge detection

Laplace filter

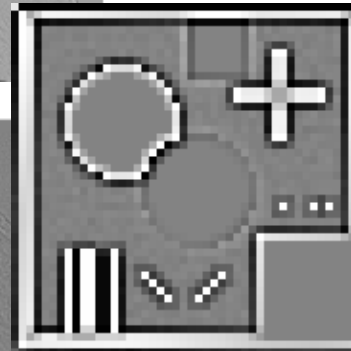
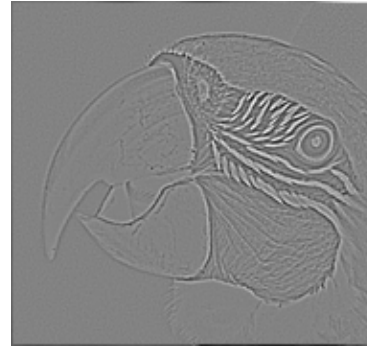
sharpened image

# Laplace operator

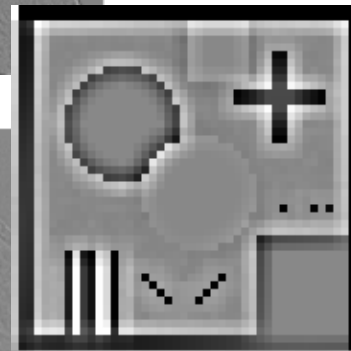
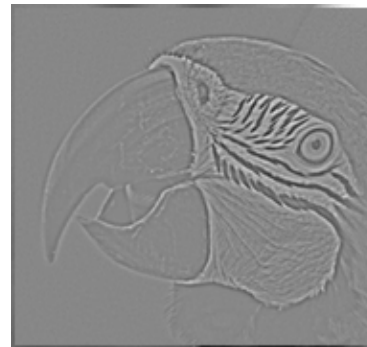
(2nd derivative)



0	1	0
1	-4	1
0	1	0

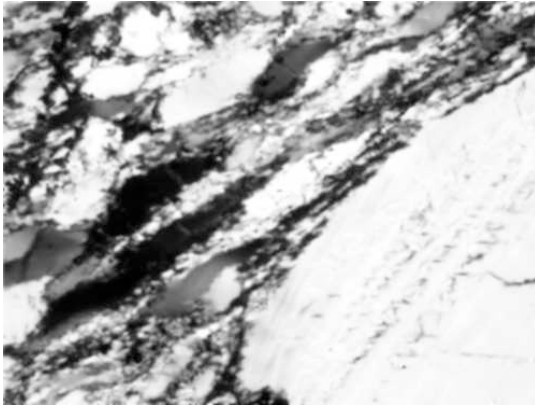


1	1	1
1	-8	1
1	1	1

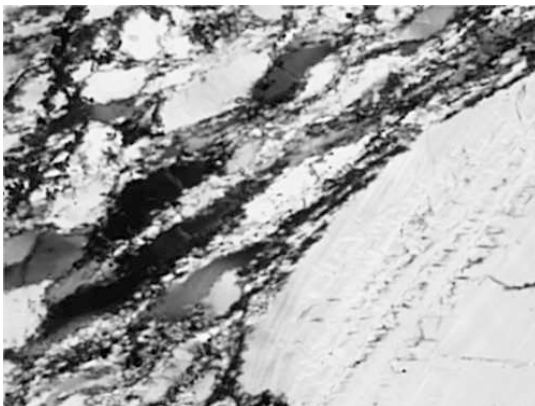
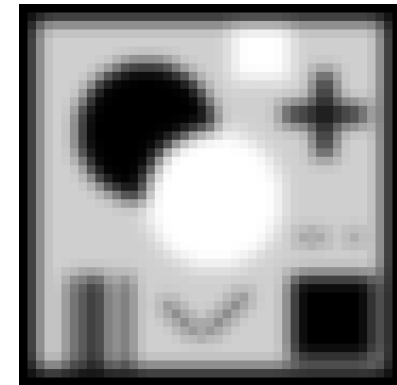


1	1	1	1	1
1	1	1	1	1
1	1	-24	1	1
1	1	1	1	1
1	1	1	1	1

# Laplace for sharpening

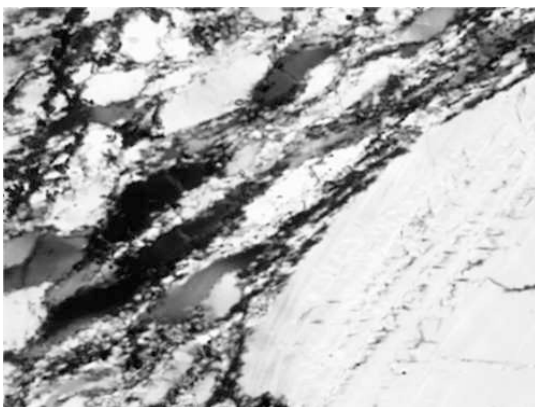
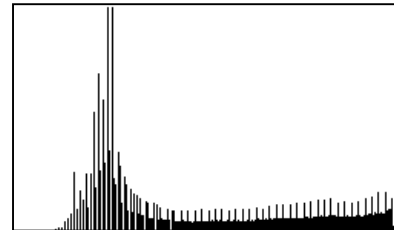


original



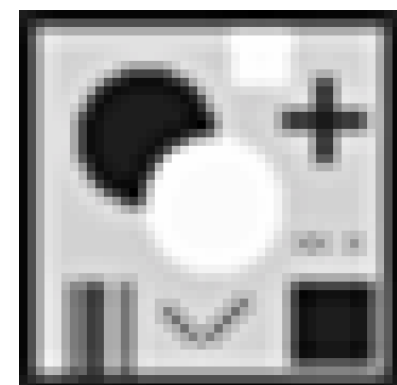
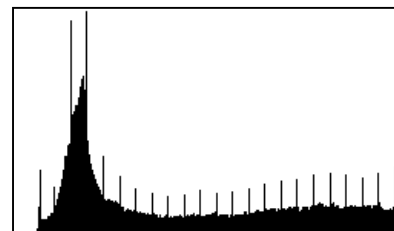
-1	-1	-1	-1	-1
-1	-1	-1	-1	-1
-1	-1	40	-1	-1
-1	-1	-1	-1	-1
-1	-1	-1	-1	-1

Laplace 5 · 5

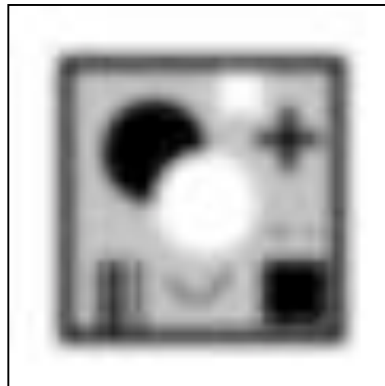
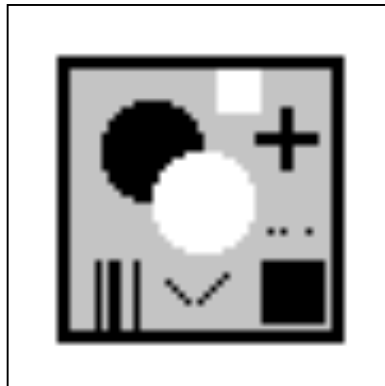


-1	-1	-1
-1	12	-1
-1	-1	-1

Laplace 3 · 3

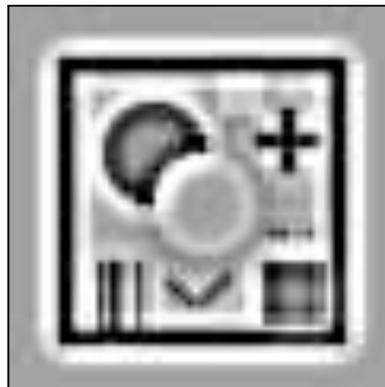


# Laplace for sharpening

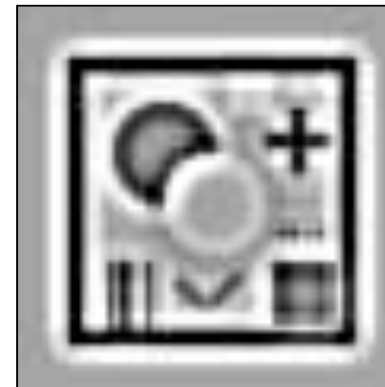


Gauss 5x5

1	1	2	1	1
1	2	4	2	1
2	4	8	4	2
1	2	4	2	1
1	1	2	1	1

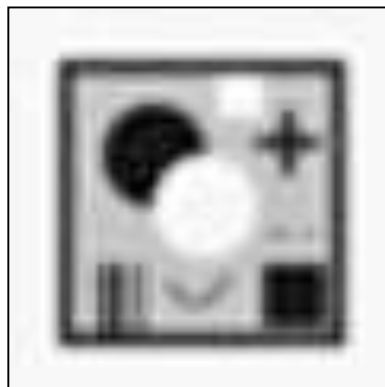


-1	-1	-2	-1	-1
-1	-2	-4	-2	-1
-2	-4	16	-4	-2
-1	-2	-4	-2	-1
-1	-1	-2	-1	-1

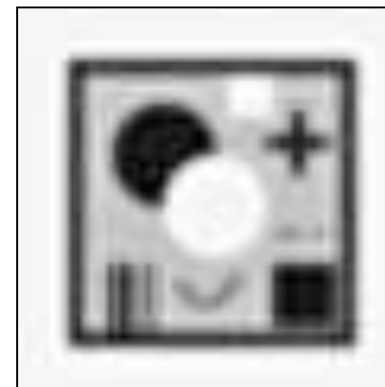


Laplace 5x5

-1	-1	-1	-1	-1
-1	-1	-1	-1	-1
-1	-1	24	-1	-1
-1	-1	-1	-1	-1
-1	-1	-1	-1	-1

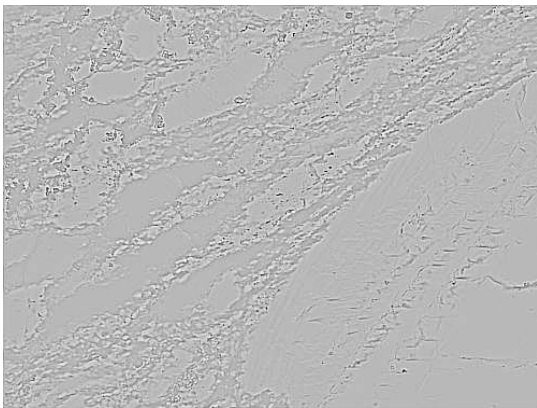
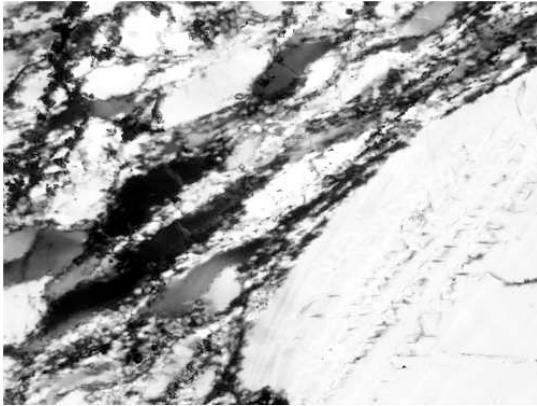


-1	-1	-2	-1	-1
-1	-2	-4	-2	-1
-2	-4	88	-4	-2
-1	-2	-4	-2	-1
-1	-1	-2	-1	-1



-1	-1	-1	-1	-1
-1	-1	-1	-1	-1
-1	-1	48	-1	-1
-1	-1	-1	-1	-1
-1	-1	-1	-1	-1

# Laplace for edge detection

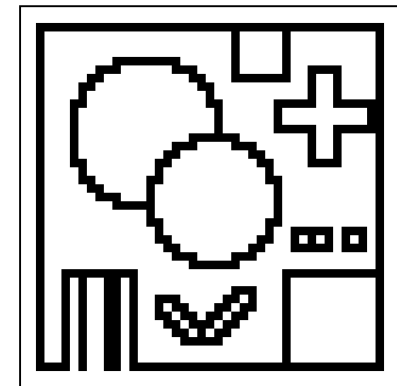
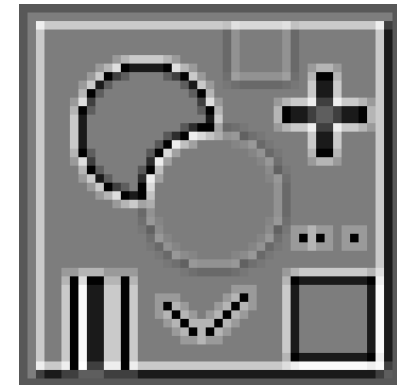
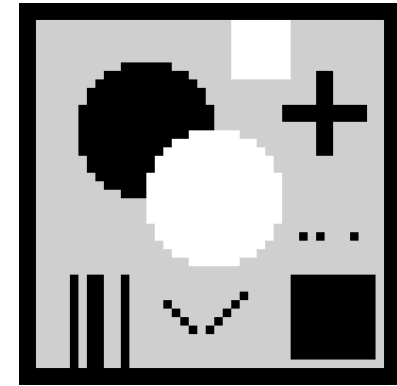
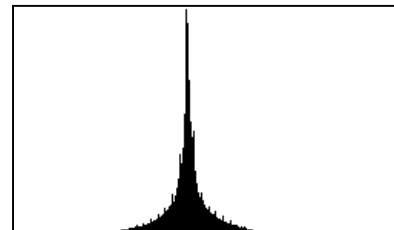
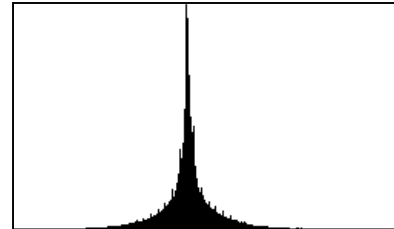


-1	-1	-1
-1	8	-1
-1	-1	-1

Laplace 3 · 3

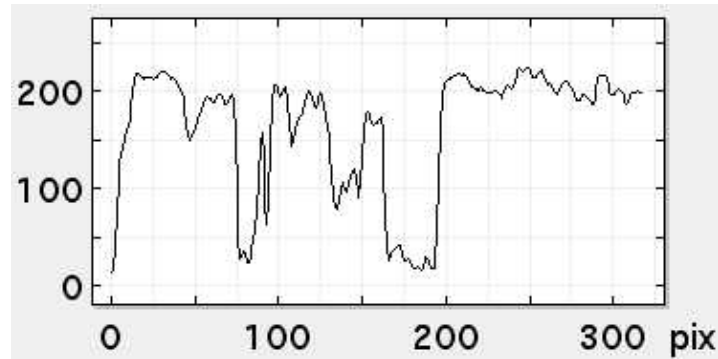
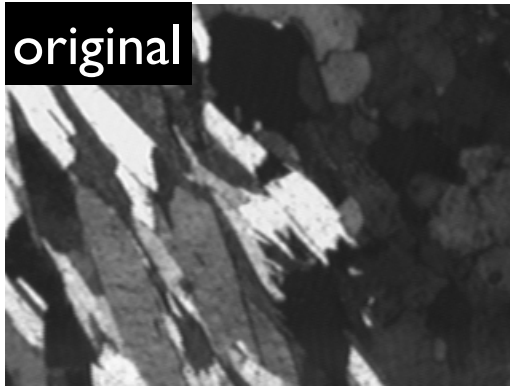
-1	-1	-1
-1	8	-1
-1	-1	-1

Laplace 3 · 3

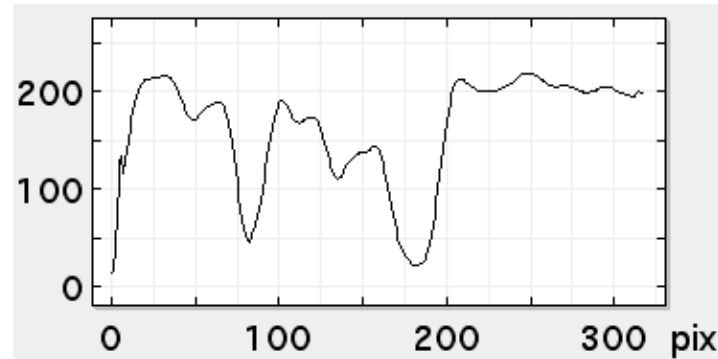
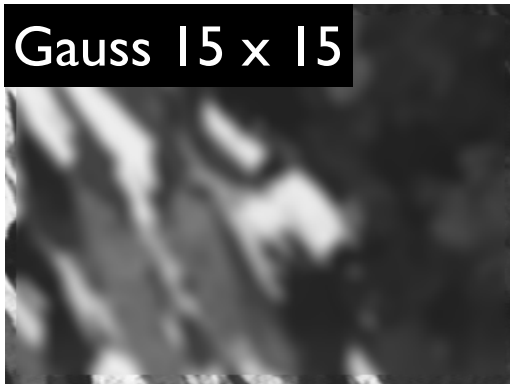




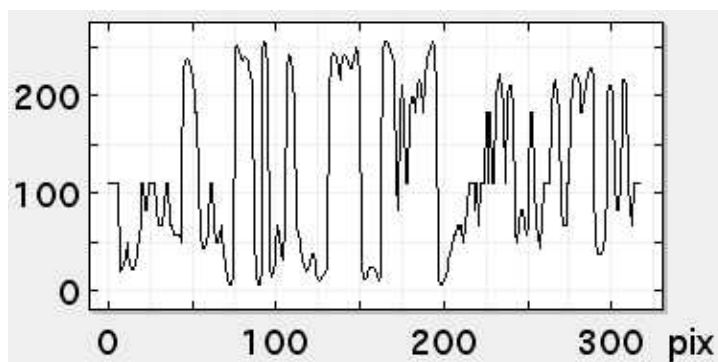
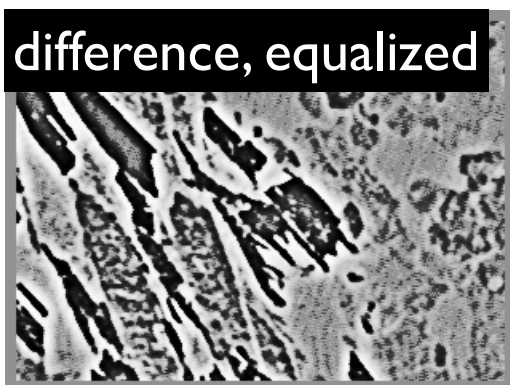
# Difference: Gaussian - Original



original



Gauss 15X15



difference

image

horizontal traverse

# Übung 18 - NOP segmentierung

Segmentierung mit neighborhood operation

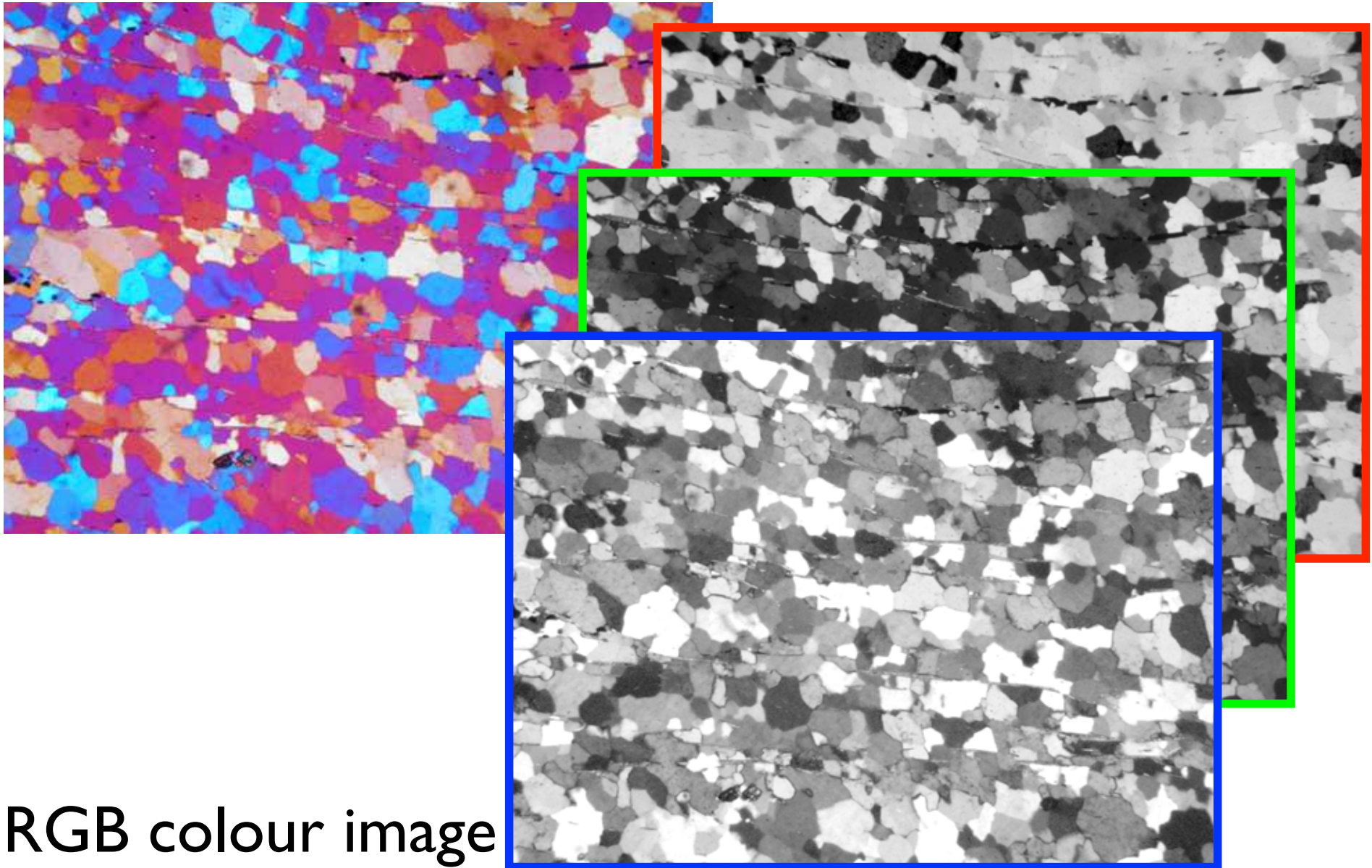
- Öffnen das Bild Truzzo.tif (session 1)

Führen Sie ein pre-processing (welchen Prozess wählen Sie?) und anschliessend eine Segmentierung mit edge detection und ein post-processing durch.

Ziel ist eine grain boundary map.

# Lazy grainboundaries

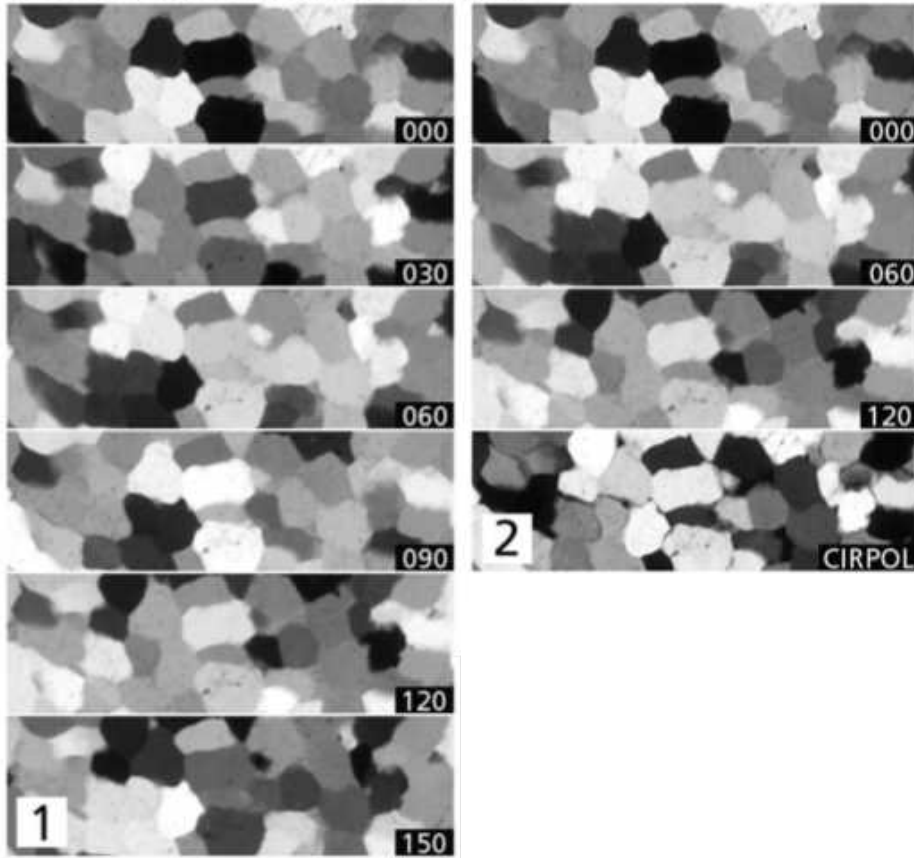
# Lazy grain boundaries input



RGB colour image

# Lazy grain boundaries input

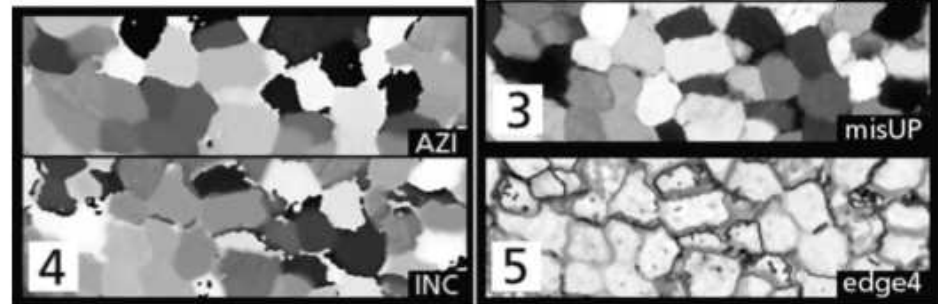
## POLARIZATION MICROGRAPHS



crosspol

crosspol  
cirpol

## MISORIENTATION IMAGES



azi / inc

misor  
edge

'orientation' images (5 types)



# Lazy / Jazy grain boundaries

earth.unibas.ch/micro

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB -- Universitätsbibliothek  
→ URZ -- Universitätsrechenzentrum  
→ VLV -- Vorlesungsverzeichnis  
→ PERSSEARCH -- Personensuche



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STRUKTURGEOLOGIE

ROCK DEFORMATION

group

software

LAZY macros

workshops

chapters

extras

examples

PDFs

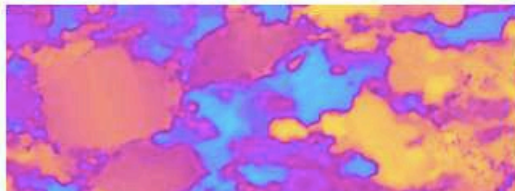
IMAGE ANALYSIS BOOK

LAZY MACROS

LAZY GRAIN BOUNDARIES

[\(back to overview\)](#)

INTRODUCTION



micrograph of quartzite with crossed polarizers and lambda plate



bitmap showing grains in black and grain boundaries in white

Uses different of images of same area.  
Originally written to analyze a

- stack of misorientation images or
- differently polarized images

but can also be used for any

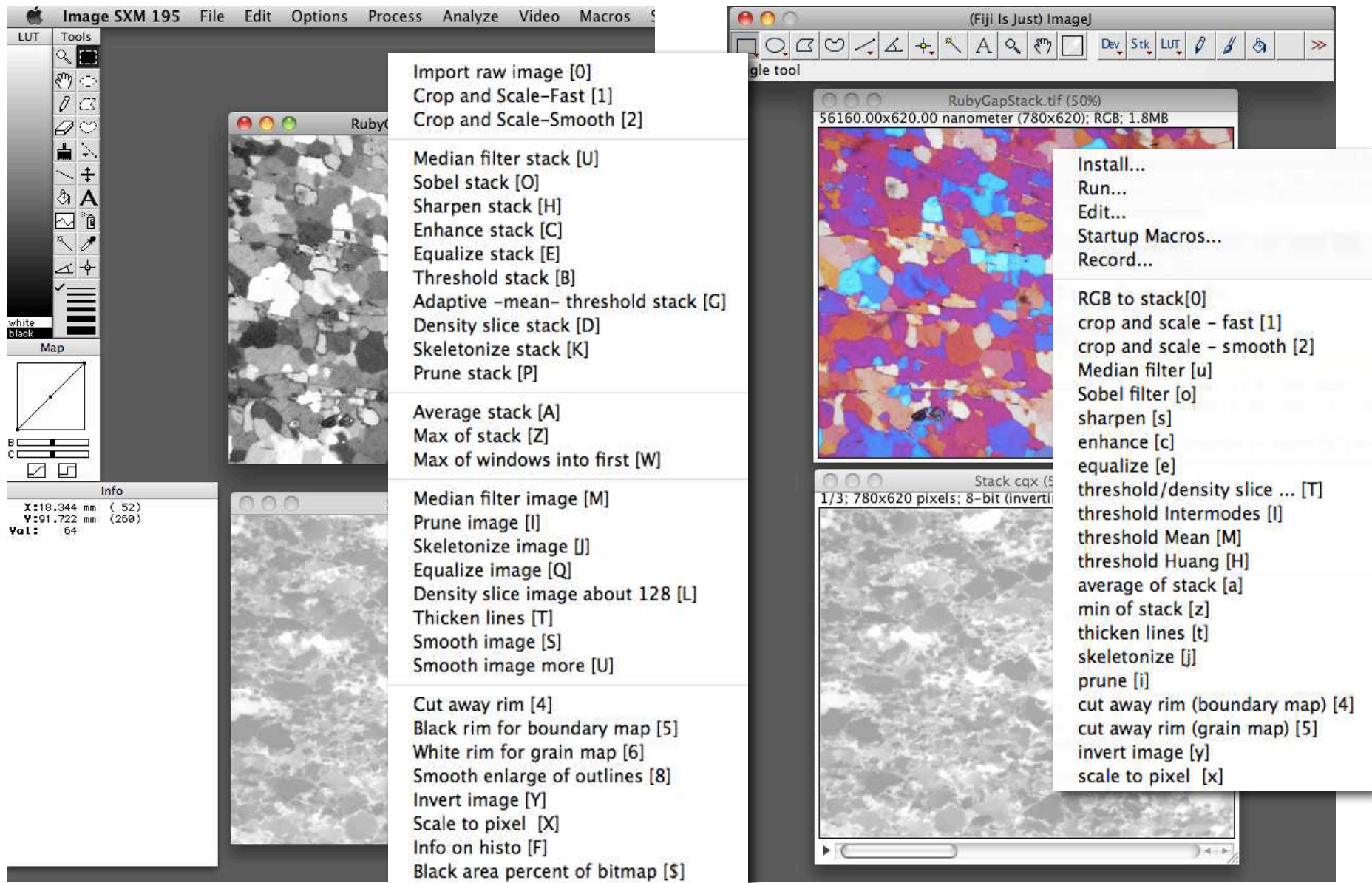
- multichannel image e.g. RGB stack

Journal of Structural Geology 22 (2000) 969–981

Automatic grain boundary detection and grain size analysis using  
polarization micrographs or orientation images

Renée Heilbronner\*

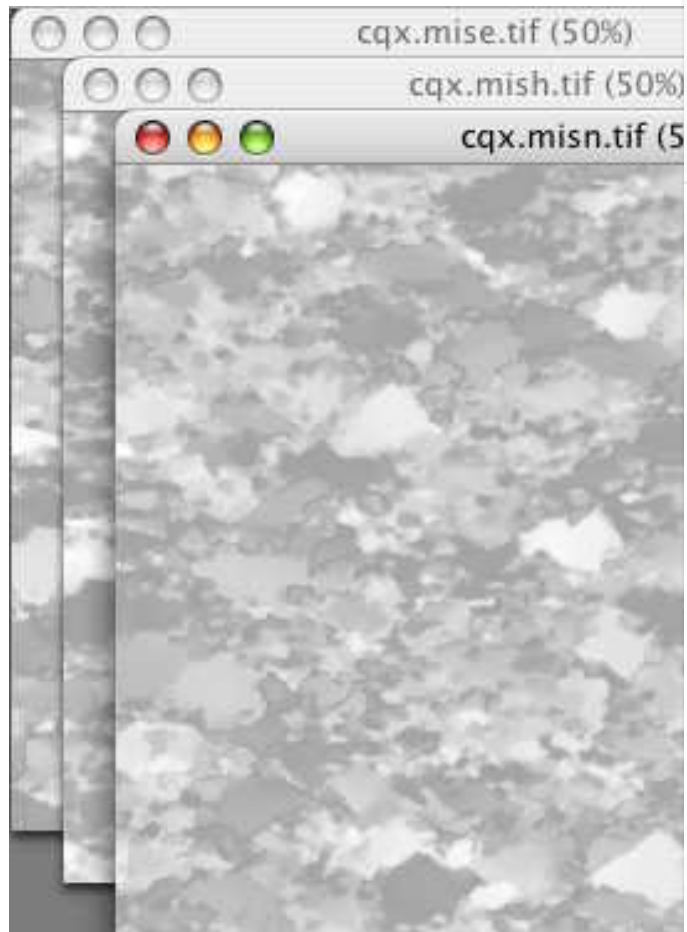
# Image SXM and Fiji / imageJ





# Lazy grain boundaries

use stack

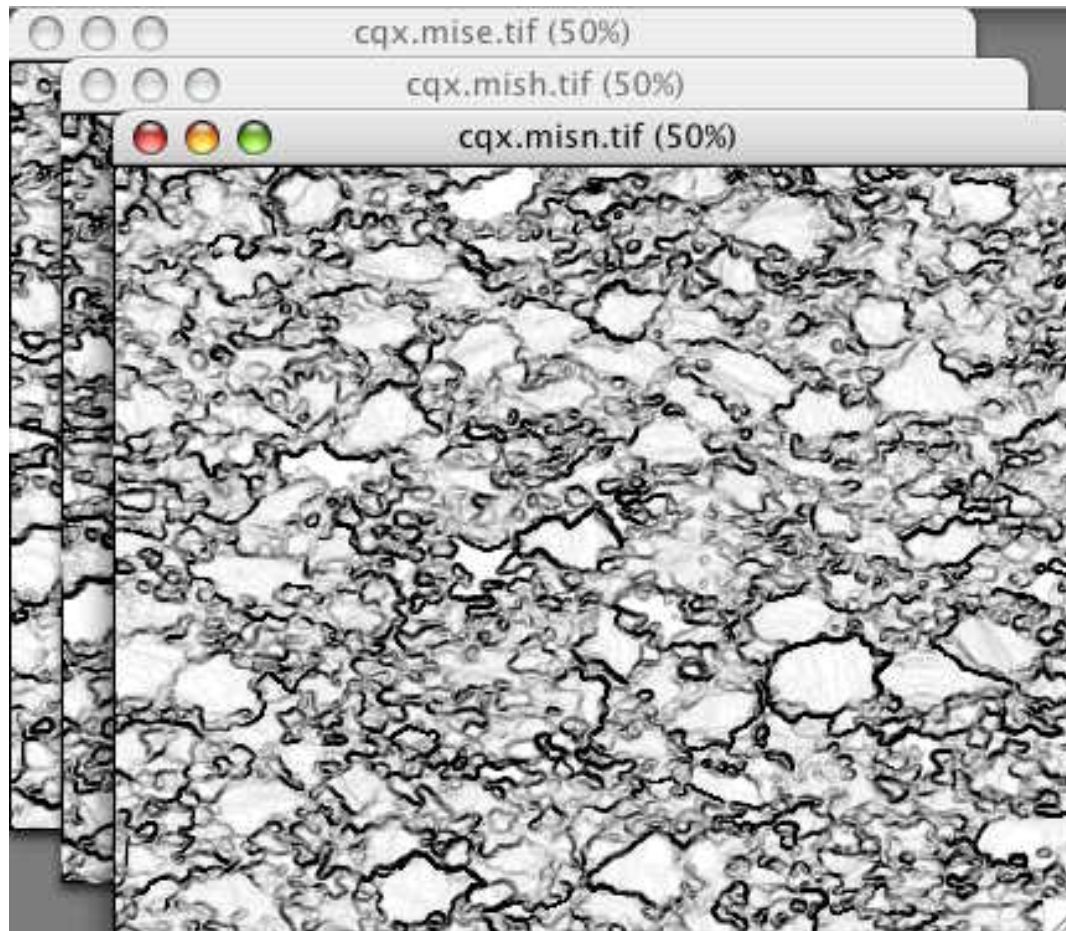


- Install...
- Run...
- Edit...
- Startup Macros...
- Record...
- RGB to stack [0]
- crop and scale - fast [1]
- crop and scale - smooth [2]
- Median filter [u]
- Sobel filter [o]
- sharpen [s]
- enhance [c]
- equalize [e]
- threshold/density slice ... [T]
- threshold Intermodes [I]
- threshold Mean [M]
- threshold Huang [H]
- average of stack [a]
- min of stack [z]
- thicken lines [t]
- skeletonize [j]
- prune [i]
- cut away rim (boundary map) [4]
- cut away rim (grain map) [5]
- invert image [y]
- scale to pixel [x]

- Import raw image [0]
- Crop and Scale-Fast [1]
- Crop and Scale-Smooth [2]
- Median filter stack [U]
- Sobel stack [O]
- Sharpen stack [H]
- Enhance stack [C]
- Equalize stack [E]
- Threshold stack [B]
- Adaptive -mean- threshold stack [G]
- Density slice stack [D]
- Skeletonize stack [K]
- Prune stack [P]
- Average stack [A]
- Max of stack [Z]
- Max of windows into first [W]
- Median filter image [M]
- Prune image [I]
- Skeletonize image [J]
- Equalize image [Q]
- Density slice image about 128 [L]
- Thicken lines [T]
- Smooth image [S]
- Smooth image more [U]
- Cut away rim [4]
- Black rim for boundary map [5]
- White rim for grain map [6]
- Smooth enlarge of outlines [8]
- Invert image [Y]
- Scale to pixel [X]
- Info on histo [F]
- Black area percent of bitmap [S]

set of misorientation images

# Lazy grain boundaries

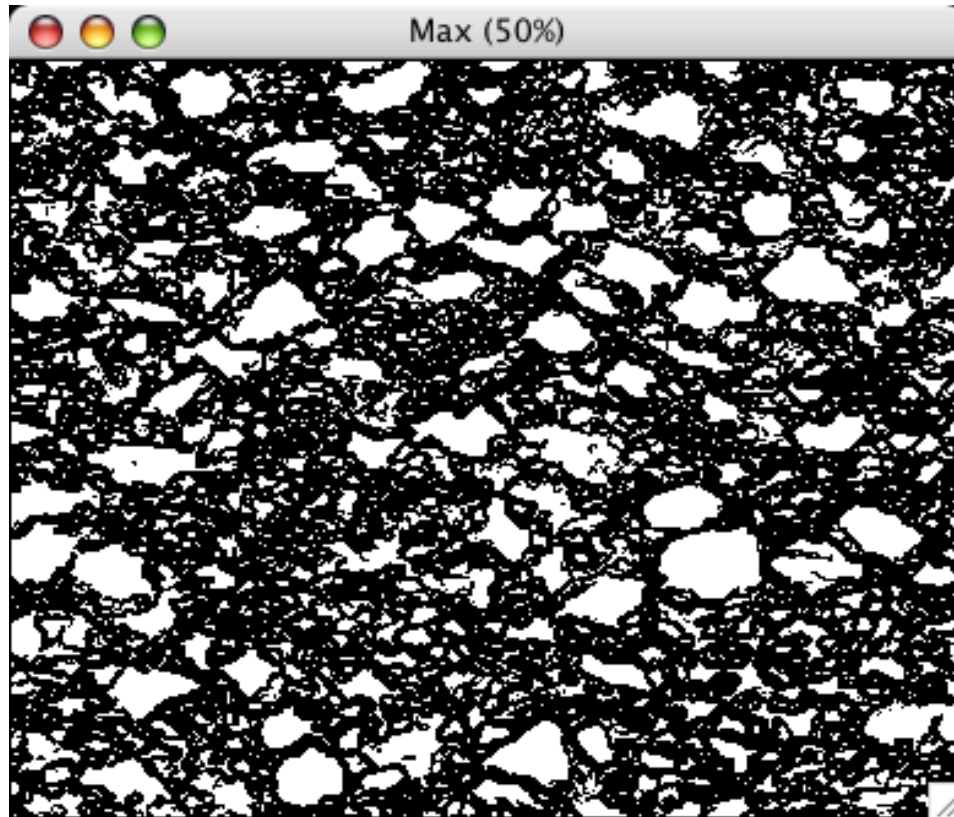


cuo

- Import raw image [0]
- Crop and Scale-Fast [1]
- Crop and Scale-Smooth [2]
- Median filter stack [U]
- Sobel stack [O]
- Sharpen stack [H]
- Enhance stack [C]
- Equalize stack [E]
- Threshold stack [B]
- Adaptive -mean- threshold stack [G]
- Density slice stack [D]
- Skeletonize stack [K]
- Prune stack [P]
- Average stack [A]
- Max of stack [Z]
- Max of windows into first [W]
- Median filter image [M]
- Prune image [I]
- Skeletonize image [J]
- Equalize image [Q]
- Density slice image about 128 [L]
- Thicken lines [T]
- Smooth image [S]
- Smooth image more [U]
- Cut away rim [4]
- Black rim for boundary map [5]
- White rim for grain map [6]
- Smooth enlarge of outlines [8]
- Invert image [Y]
- Scale to pixel [X]
- Info on histo [F]
- Black area percent of bitmap [S]



# Lazy grain boundaries

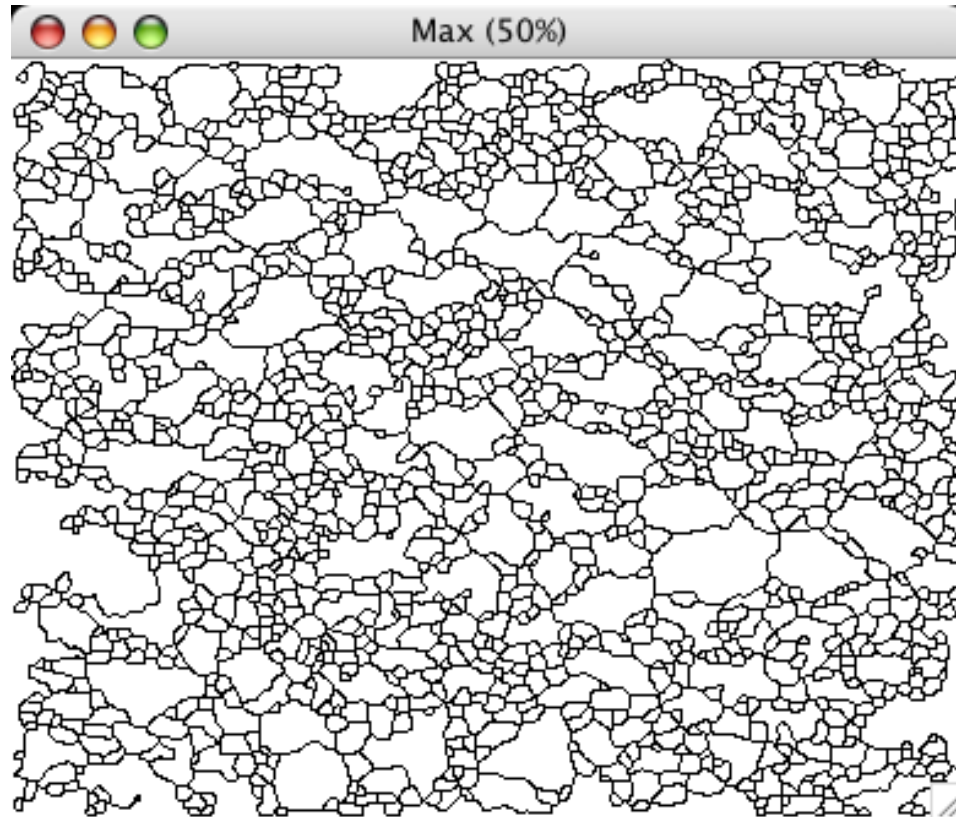


cuog-z-m

- Import raw image [0]
- Crop and Scale-Fast [1]
- Crop and Scale-Smooth [2]
- Median filter stack [U]
- Sobel stack [O]
- Sharpen stack [H]
- Enhance stack [C]
- Equalize stack [E]
- Threshold stack [B]
- Adaptive -mean- threshold stack [G]
- Density slice stack [D]
- Skeletonize stack [K]
- Prune stack [P]
- Average stack [A]
- Max of stack [Z]
- Max of windows into first [W]
- Median filter image [M]
- Prune image [I]
- Skeletonize image [J]
- Equalize image [Q]
- Density slice image about 128 [L]
- Thicken lines [T]
- Smooth image [S]
- Smooth image more [U]
- Cut away rim [4]
- Black rim for boundary map [5]
- White rim for grain map [6]
- Smooth enlarge of outlines [8]
- Invert image [Y]
- Scale to pixel [X]
- Info on histo [F]
- Black area percent of bitmap [S]



# Lazy grain boundaries



cuog-z-m-ji-tji-tji

Import raw image [0]  
Crop and Scale-Fast [1]  
Crop and Scale-Smooth [2]

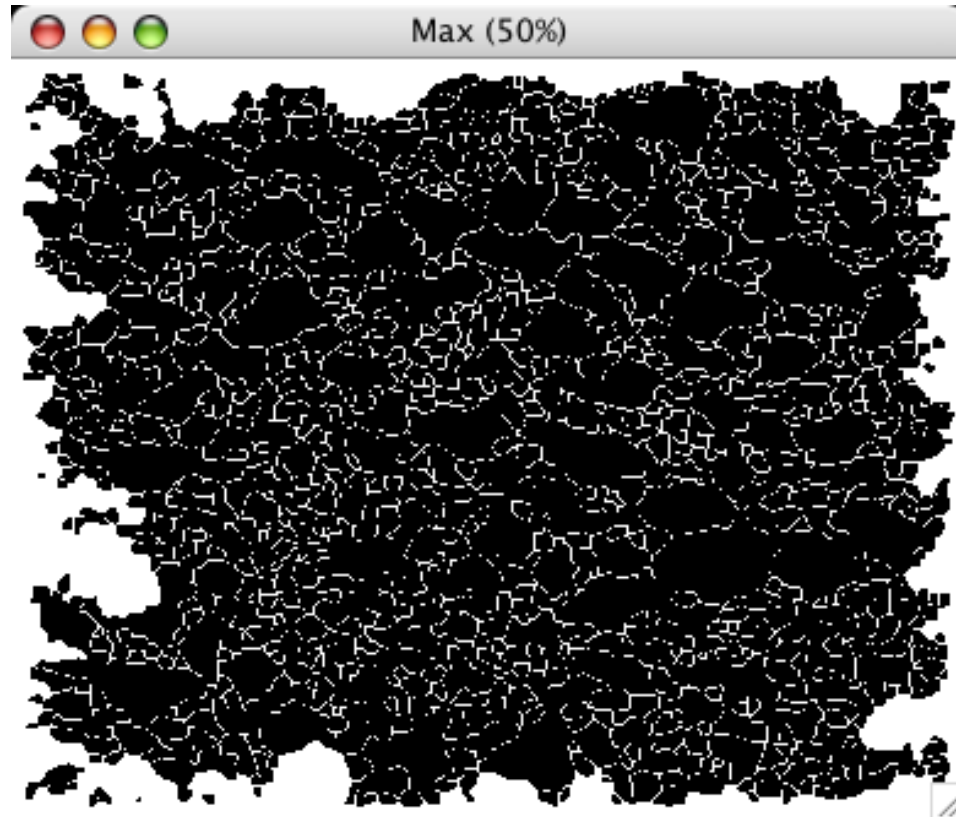
Median filter stack [U]  
Sobel stack [O]  
Sharpen stack [H]  
Enhance stack [C]  
Equalize stack [E]  
Threshold stack [B]  
Adaptive -mean- threshold stack [G]  
Density slice stack [D]  
Skeletonize stack [K]  
Prune stack [P]

Average stack [A]  
Max of stack [Z]  
Max of windows into first [W]

Median filter image [M]  
Prune image [I]  
Skeletonize image [J]  
Equalize image [Q]  
Density slice image about 128 [L]  
Thicken lines [T]  
Smooth image [S]  
Smooth image more [U]

Cut away rim [4]  
Black rim for boundary map [5]  
White rim for grain map [6]  
Smooth enlarge of outlines [8]  
Invert image [Y]  
Scale to pixel [X]  
Info on histo [F]  
Black area percent of bitmap [S]

# Lazy grain boundaries



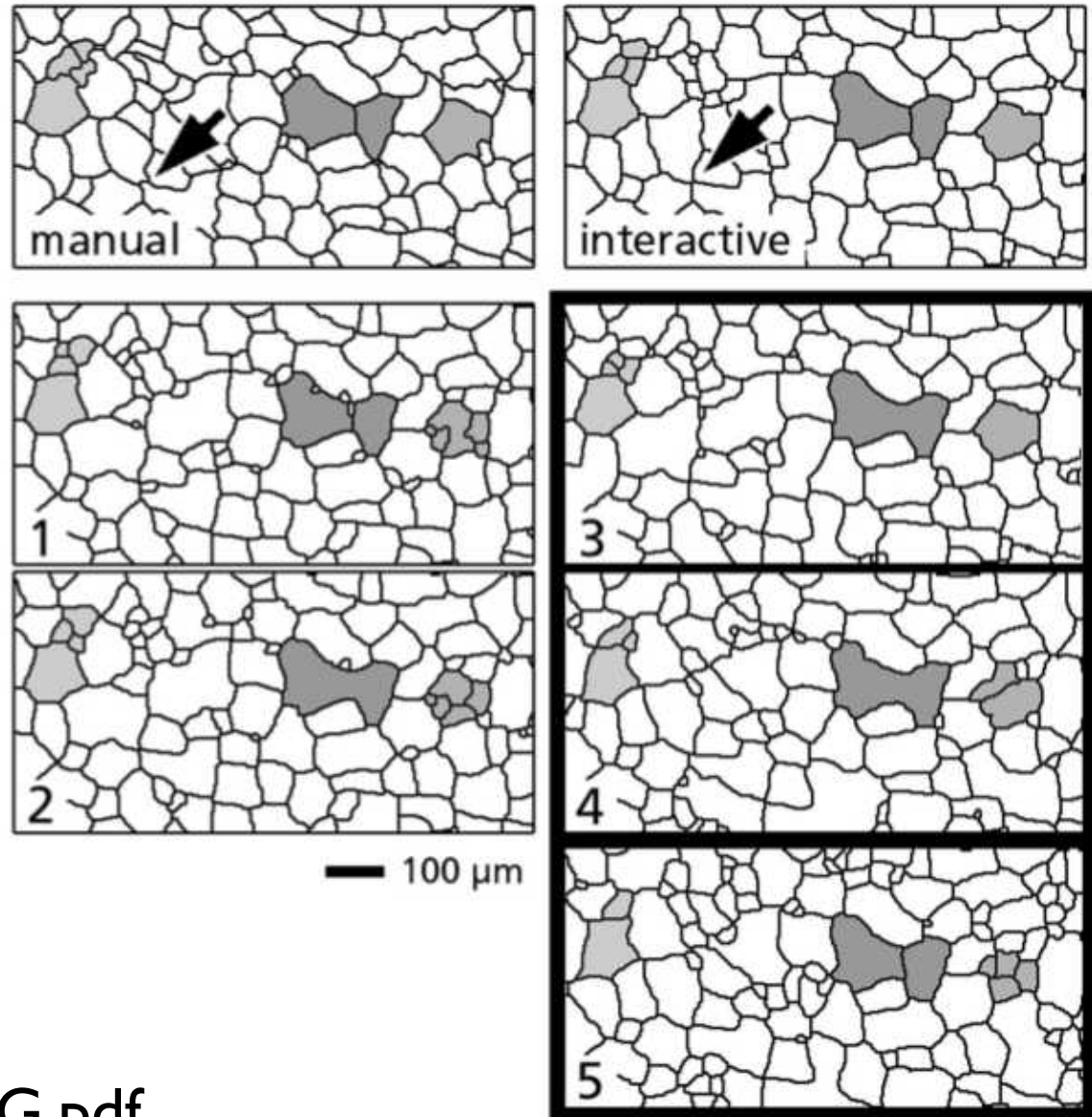
cuog-z-m-ji-tji-tji-t5y

- Import raw image [0]
- Crop and Scale-Fast [1]
- Crop and Scale-Smooth [2]
- Median filter stack [U]
- Sobel stack [O]
- Sharpen stack [H]
- Enhance stack [C]
- Equalize stack [E]
- Threshold stack [B]
- Adaptive -mean- threshold stack [G]
- Density slice stack [D]
- Skeletonize stack [K]
- Prune stack [P]
- Average stack [A]
- Max of stack [Z]
- Max of windows into first [W]
- Median filter image [M]
- Prune image [I]
- Skeletonize image [J]
- Equalize image [Q]
- Density slice image about 128 [L]
- Thicken lines [T]
- Smooth image [S]
- Smooth image more [U]
- Cut away rim [4]
- Black rim for boundary map [5]
- White rim for grain map [6]
- Smooth enlarge of outlines [8]
- Invert image [Y]
- Scale to pixel [X]
- Info on histo [F]
- Black area percent of bitmap [S]

# Lazy grain boundaries

typical artefacts  
of segmentation:

- corner of 4
- oversegmentation
- 45° diagonals



→ 2000\_RH\_Lazygbd\_JSG.pdf

# Übung 19 - Lazy grainboundaries

Segmentierung mit neighborhood operation

■ Öffnen das den das Bild RubyGapSheet5.tif

Laden Sie das Lazy Grain boundaries macro und führen Sie eine Segmentierung durch

# DBA 2014


## session 7

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
→ URZ - Universitätsrechenzentrum  
→ VIA - Vorkursangebot  
→ PERSSEARCH - Personensuche

HOME Contact Studium Geowissenschaften Lehrveranstaltungen Vorträge und Links Strukturgeologie  
Rock Information Projects & Software Workshops Textbook DDM Macros Image Macros Image Analysis

LEHRVERANSTALTUNGEN



...ceci n'est pas "L'appel des cimes" de René Magritte...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehalle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageDM bzw. image kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageDM software (MacOSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Estimation (2-D -> 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formalanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software Image DM, bzw. image (alle public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungbestellung möglich)
- Harterter, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET** [earth.unibas.ch](http://earth.unibas.ch)  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

TROMSDO GEOMAGING

→ TROMSDO CRISTAL DYNAMICS HOMEPAGE (English)  
→ TROMSDO GEOLOGY HOMEPAGE (Norwegian)  
→ TROMSDO UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>



# Semesterfahrplan: Fahrplanänderung

			Freitag CR 14-17	Montag CR 14-17
	Thema	Doz.	Gruppe A	Gruppe B
1	Images for image analysis - intro: ImageSXM	RH	19-Sep-2014	22-Sep-2014
2	Digital Images - Pixels - LUTs	RH	26-Sep-2014	29-Sep-2014
3	Explore / pre-process digital images - intro: imageJ	RK	3-Oct-2014	6-Oct-2014
4	POP segmentation - post-processing	RK	10-Oct-2014	13-Oct-2014
5	Mathem./Punkt-Operationen Verschneide-Operationen	RH	17-Oct-2014	
		RH		27-Oct-2014
	(fällt aus)			
			nur Freitag CR 14-17	
6	Filtern - Kantendetektion - NOP segmentation	RH	7-Nov-2014	
7	Analyze: segments - best-fit ellipses - property maps	RH	14-Nov-2014	
8	Fourier-Transformationen Autokorrelation	RH	21-Nov-2014	
	(Dies Academicus)			
9	Korngrößen-Analyse Stereologie - Kontaktflächen	RH	5-Dec-2014	
Test			12-Dec-2014	

pro Nachmittag: 1. Teil: Vorlesung (Einführung in das Thema) - 2. Teil: Übungen  
Besprechung der Übungen am Anfang der nächsten Vorlesung

# Übung 18 - NOP segmentierung

Segmentierung mit neighborhood operation

■ Öffnen das Bild Truzzo.tif (session I)

Führen Sie ein pre-processing (welchen Prozess wählen Sie?) und anschliessend eine Segmentierung mit edge detection und ein post-processing durch.

Ziel ist eine grain boundary map.

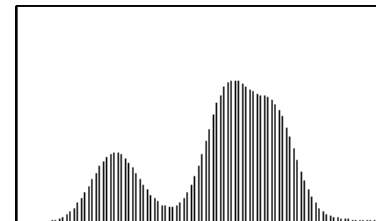
Was muss man tun?

Truzzo\_1scaled.tif

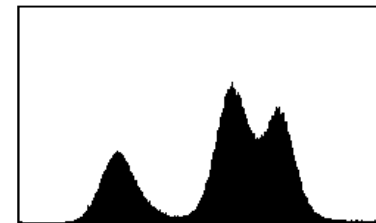
Truzzo\_2crop.tif

Truzzo\_3resize.tif

```
Name: Truzzo_2crop.tif
Folder: root/Users/renee/Desktop
SXM Type: Not SXM
Format: Not specified
Width: 345.631 µm (1424)
Height: 244.668 µm (1008)
Size: 1402 Kb
Created: Thu, Nov 13, 2014 9:31:29 PM
Modified: Thu, Nov 13, 2014 9:31:29 PM
Type: TIFF
Comp: None
LUT: Grayscale (256, 0-255)
Mag: 100%
XY scale: 0.24272 µm/pixel
Z scale: None
No Selection
```



```
Name: Untitled
Folder: << none >>
SXM Type: Not SXM
Format: Not specified
Width: 345.631 µm (691)
Height: 244.593 µm (489)
Size: 330 Kb
Type: New
Comp: None
LUT: Grayscale (256, 0-255)
Mag: 100%
XY scale: 0.50019 µm/pixel
Z scale: None
No Selection
```



Set Scale

Measured Distance: 0.00 pixels

Known Distance: 0.00

Pixel Aspect Ratio: 1.0000

Units: Micrometers

Scale: 1.99924 pixels per µm

Cancel OK

# Übung 18 - NOP segmentierung

Segmentierung mit neighborhood operation

■ Öffnen das Bild Truzzo.tif (session 1)

Führen Sie ein pre-processing (welchen Prozess wählen Sie?) und anschliessend eine Segmentierung mit edge detection und ein post-processing durch.

Ziel ist eine grain boundary map.

Was muss man tun?

Truzzo\_3resize.tif

Truzzo\_4medianx3.tif

Truzzo\_5sobel.tif

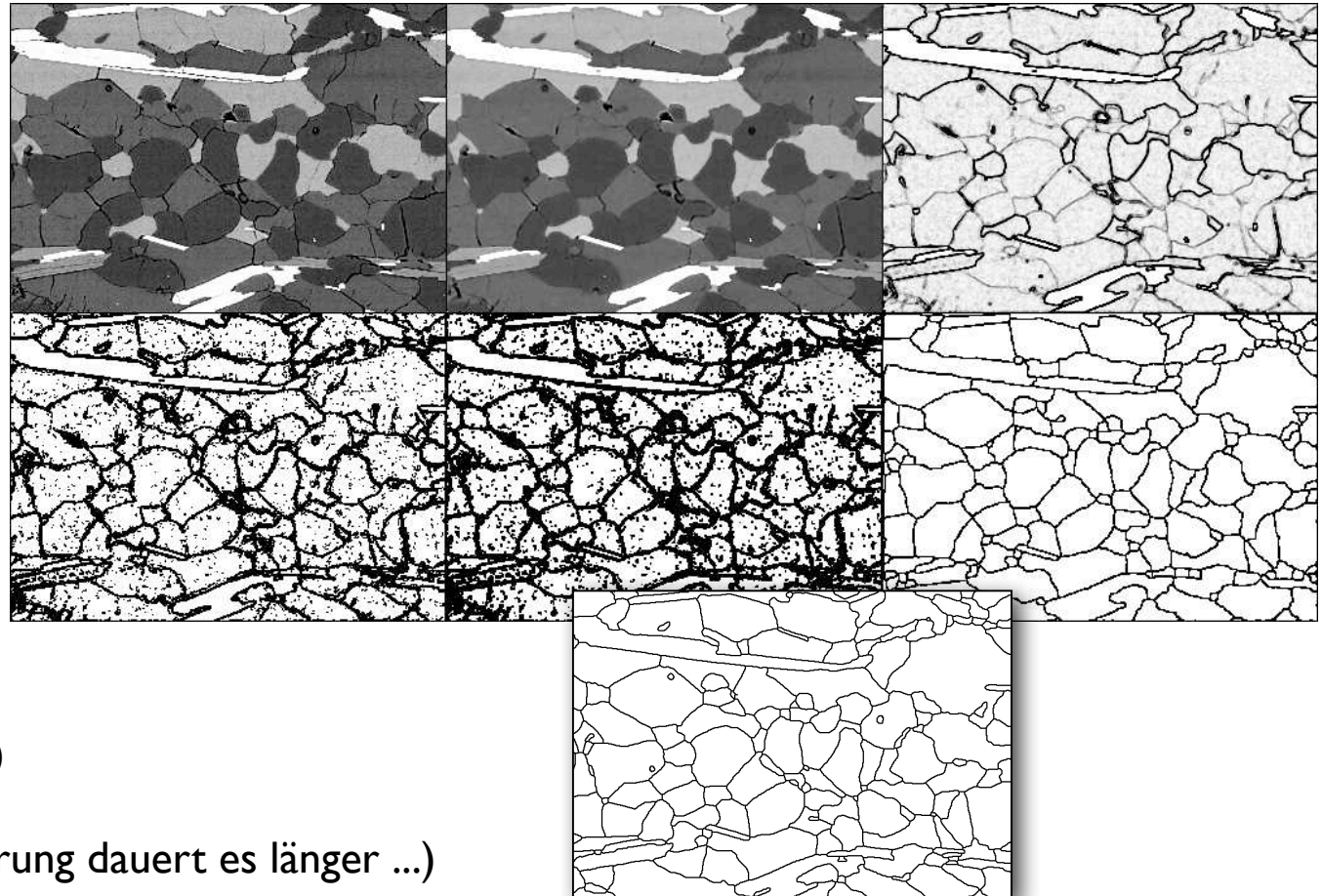
Truzzo\_6theshold30.tif

Truzzo\_7handfixedbrush4.tif

Truzzo\_8itjit.tif

(Zeitaufwand ca. 15 Minuten)

(für eine perfekte Segmentierung dauert es länger ...)



# image analysis steps

# was bisher geschah...

## image acquisition:

resolution, discretization, image size (XYZ),  
formatting, compression

## preprocessing:

Bilddaten aufbereiten: XY skalieren, Z  
kalibrieren, crop, re-size, noise reduction,  
background correction, ...

## segmentation:

depending on image model  
by greyvalue (Z): using point operations (LUTs)  
by edgedetection (XY): using gradient filters

## postprocessing:

morphological operations using structural  
filters: median, erosion, dilation, opening,  
closing, skeletonise, pruning, ... (beauty case)

Auf gut Deutsch dank

[http://de.wikipedia.org/wiki/  
Segmentierung\\_\(Bildverarbeitung\)](http://de.wikipedia.org/wiki/Segmentierung_(Bildverarbeitung)):

Zitat:

"Segmentierung ist im Prozess des  
maschinellen Sehens üblicherweise  
der erste Schritt der Bildanalyse  
und kommt nach der  
Bildvorverarbeitung.

Der Ablauf ist also:

Szene →

Bildaufnahme →

Bildvorverarbeitung →

Segmentierung →

Merkmalsextraktion →

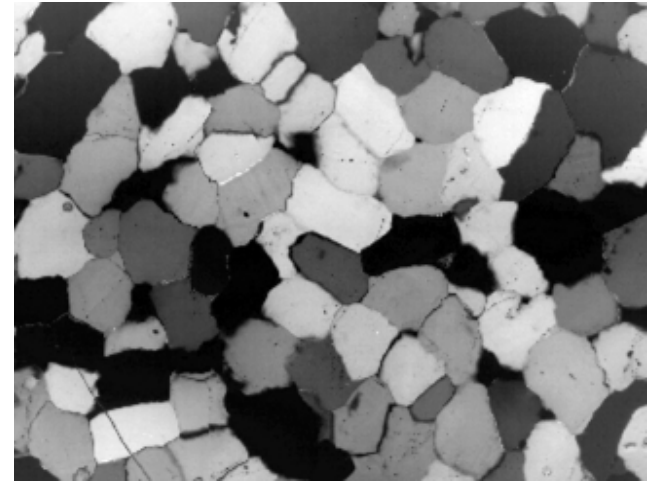
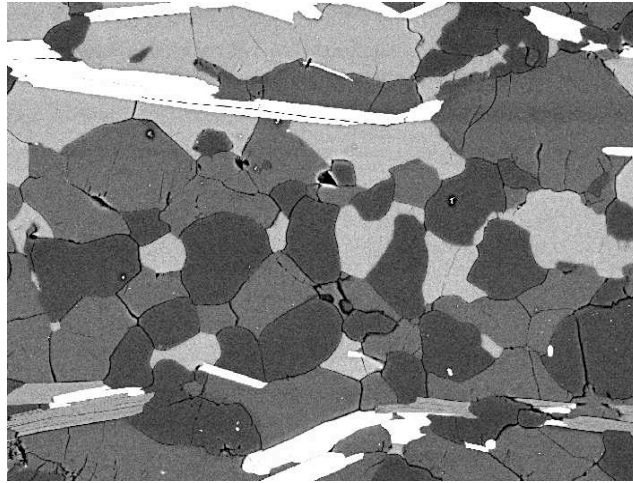
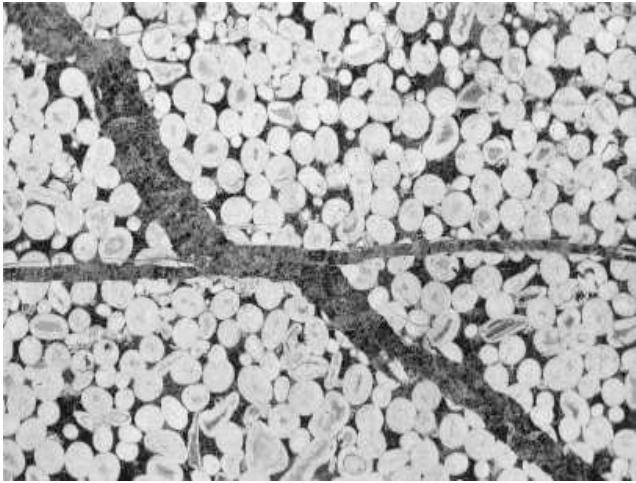
Klassifizierung →

Aussage

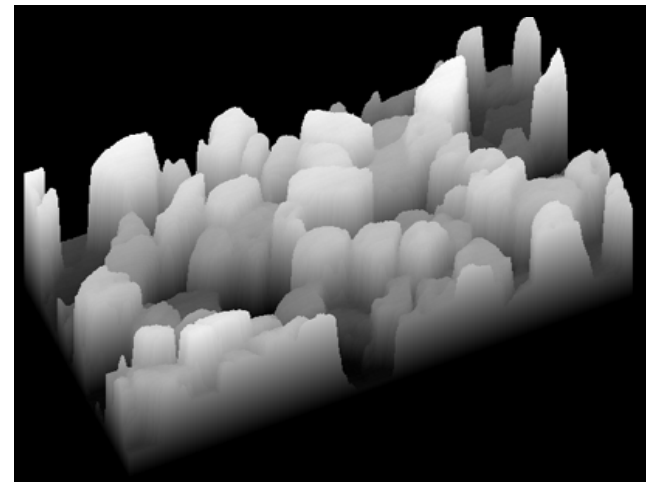
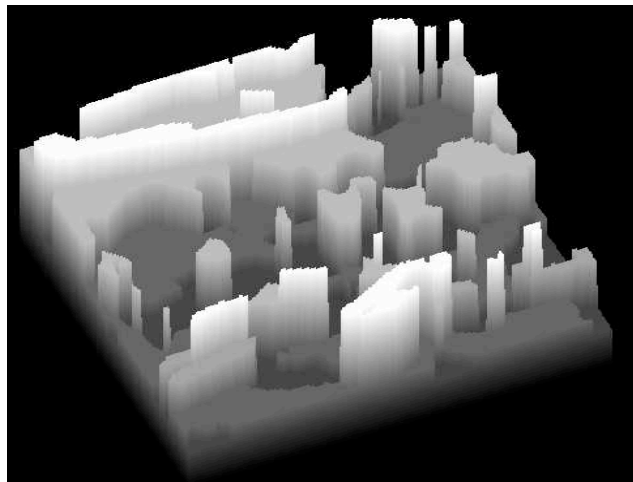
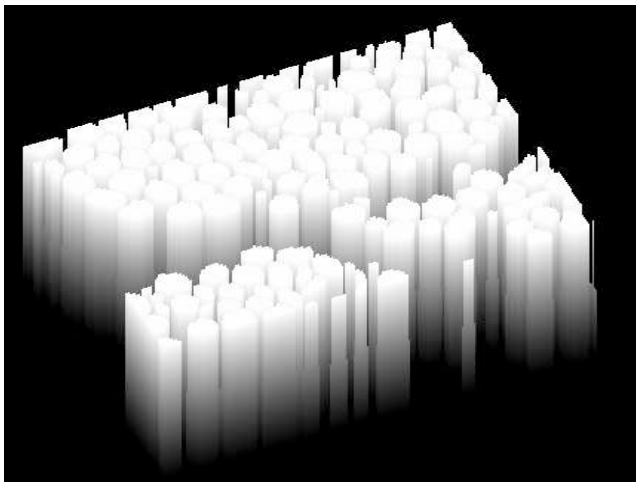
"



# Bildmodelle

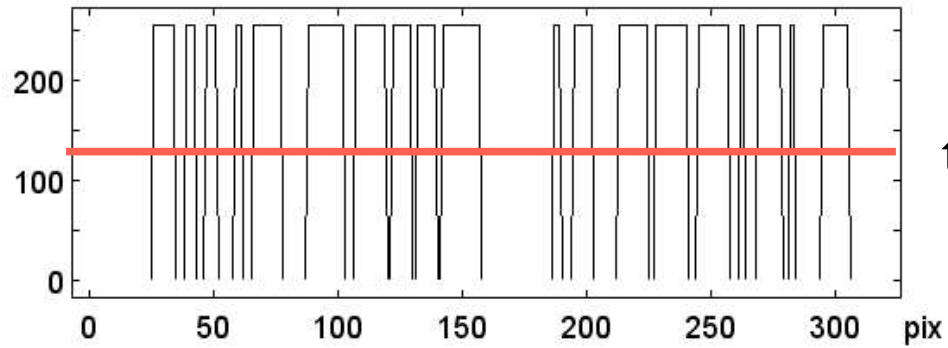
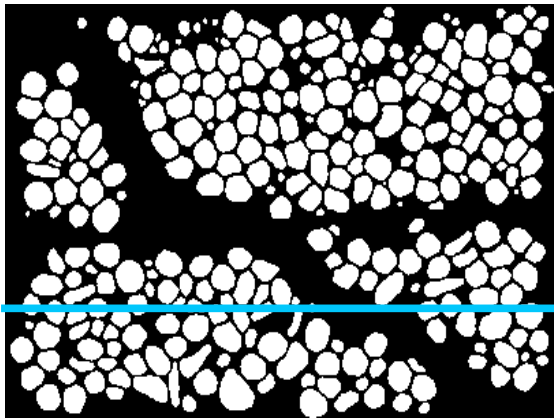


images

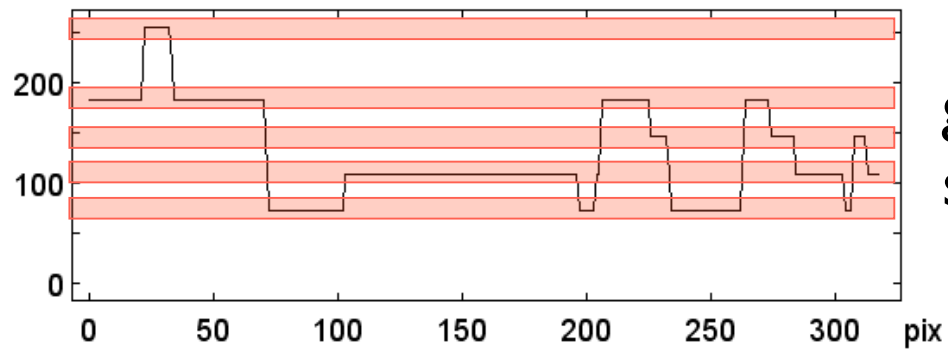
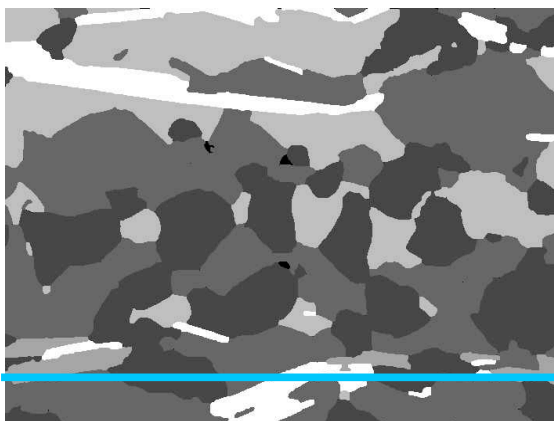


models

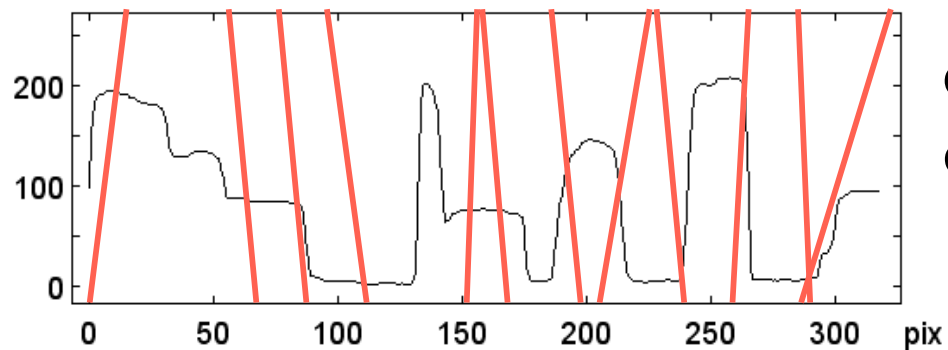
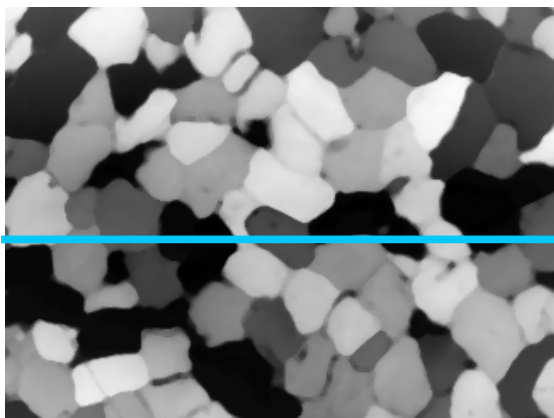
# POP oder NOP



thresholding

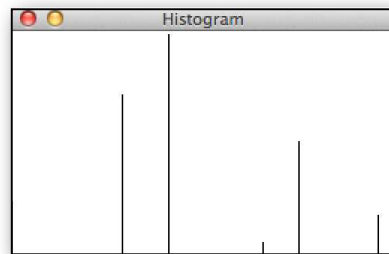
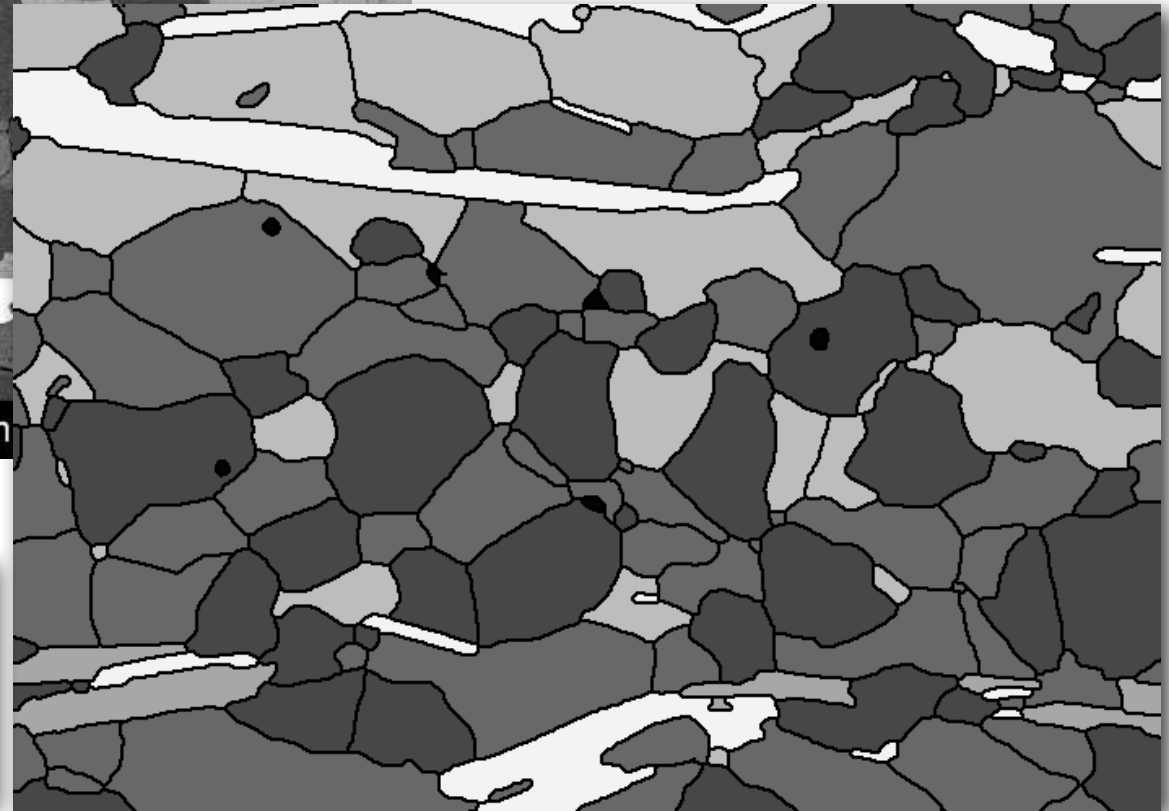
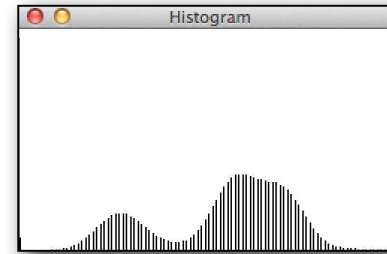
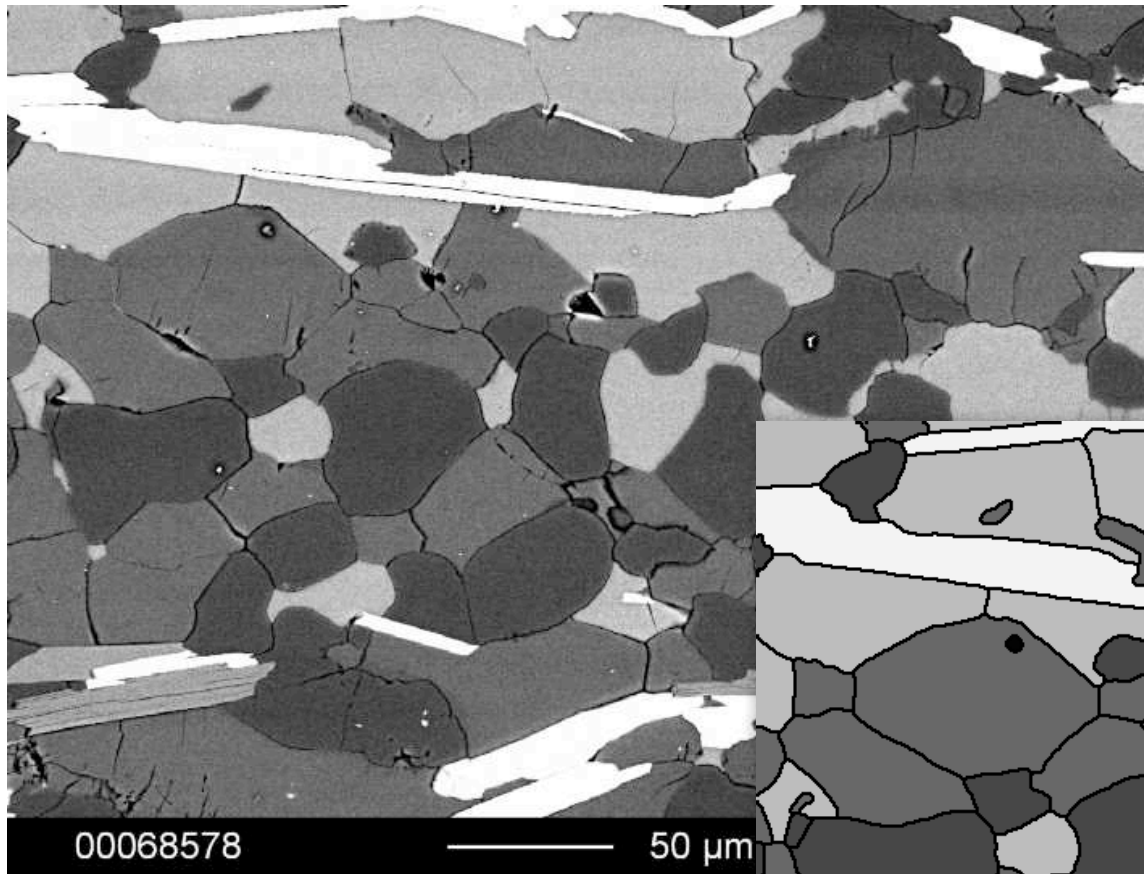


grey level  
slicing

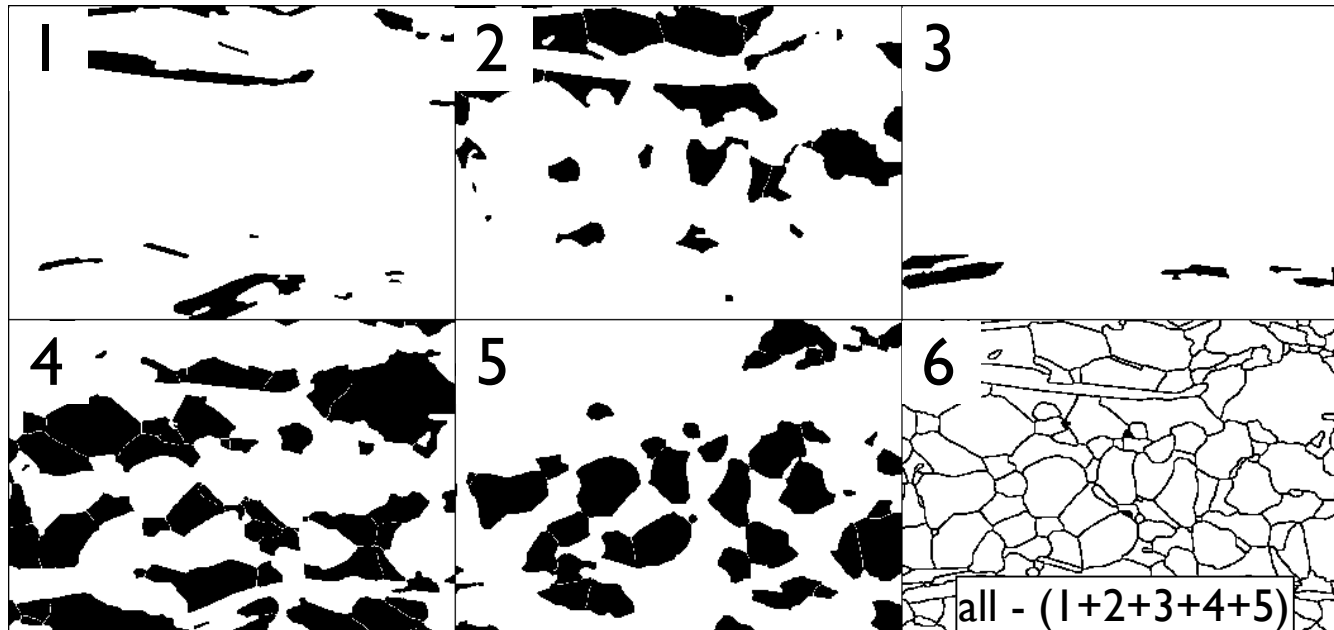


edge  
detection

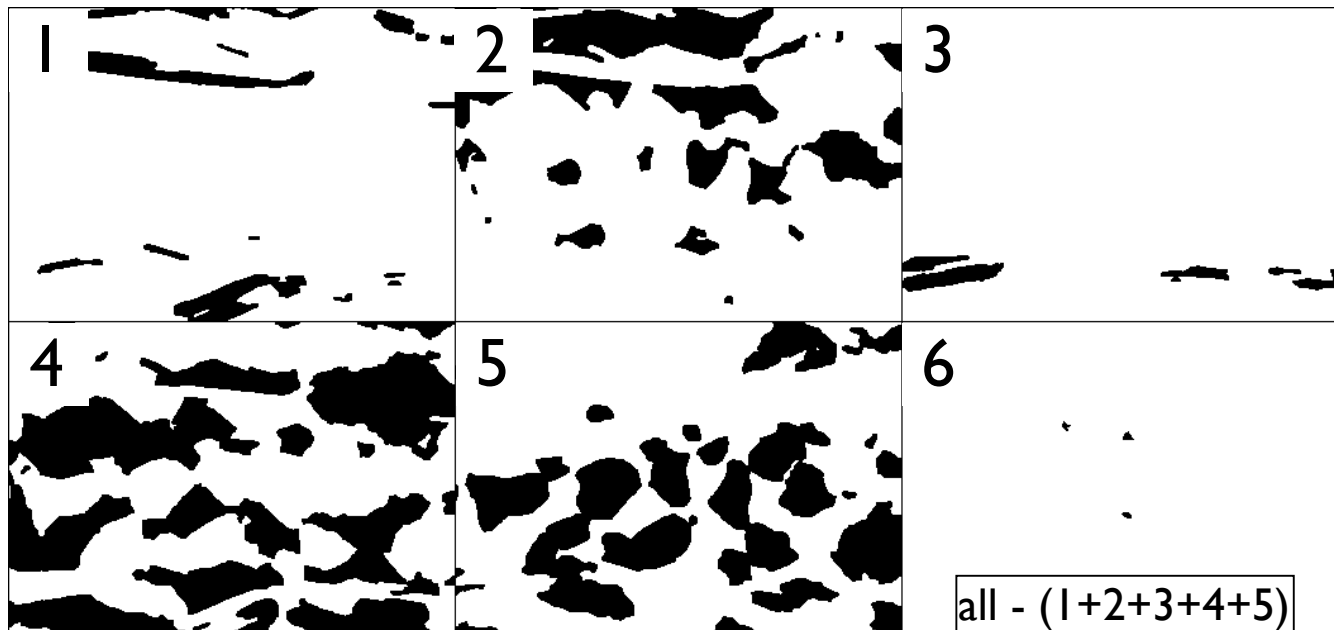
# Resultat der Bemühungen



# Binärbild - bitmap

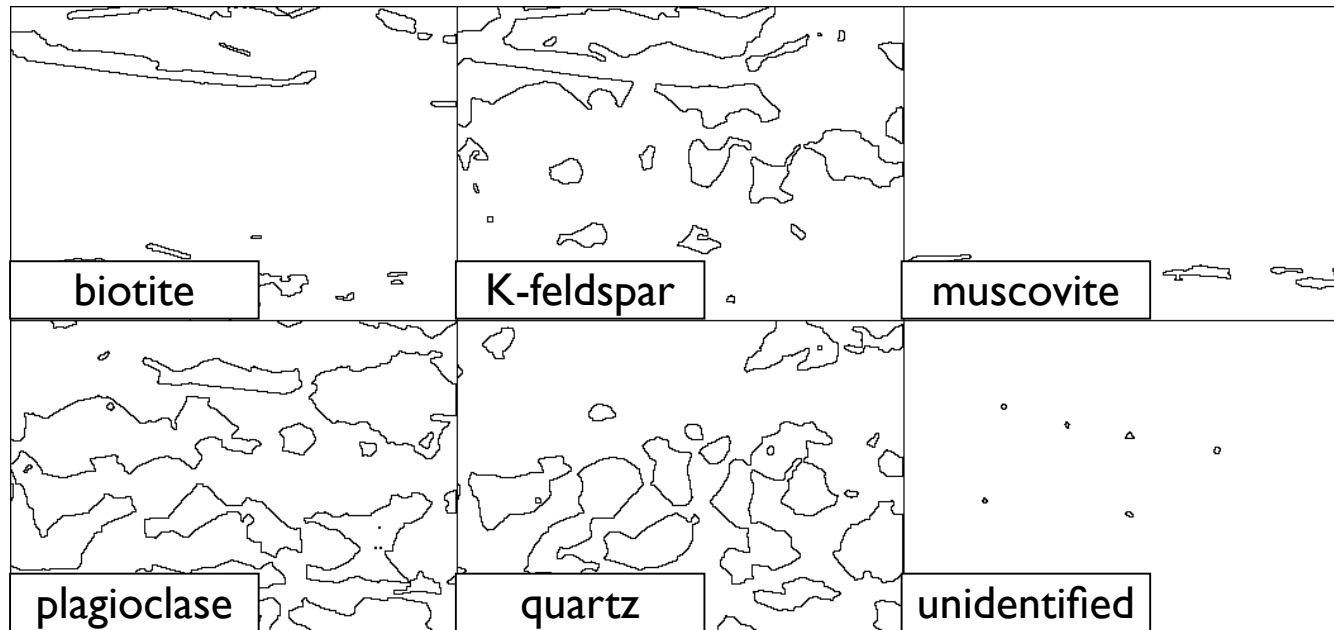


grain maps

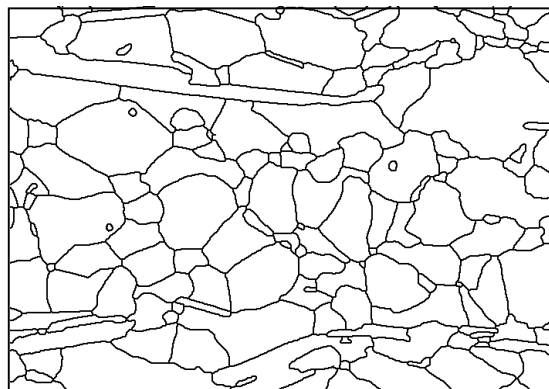


phase maps

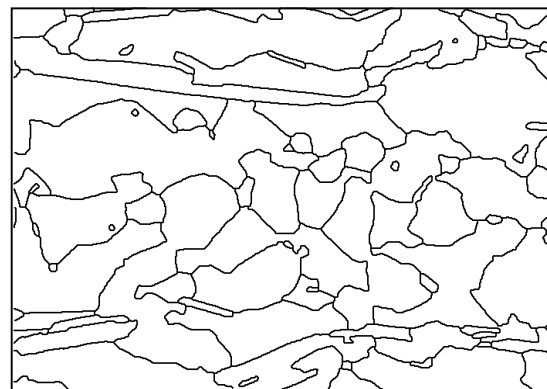
# verschiedene Grenzen



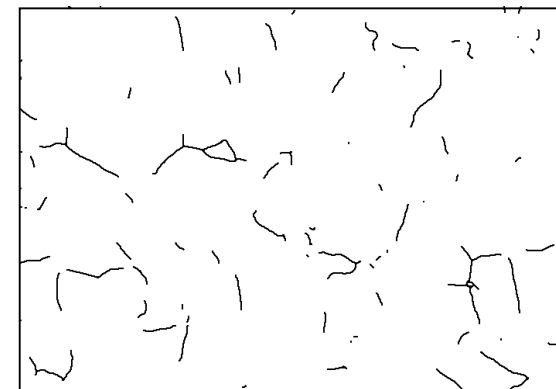
Phasengrenzen =  
Grenzfläche zwischen  
Körnern von jeweils  
einer Phase und Körnern  
aller andern Phasen



Alle Korngrenzen =  
gesamte Korngrenzfläche



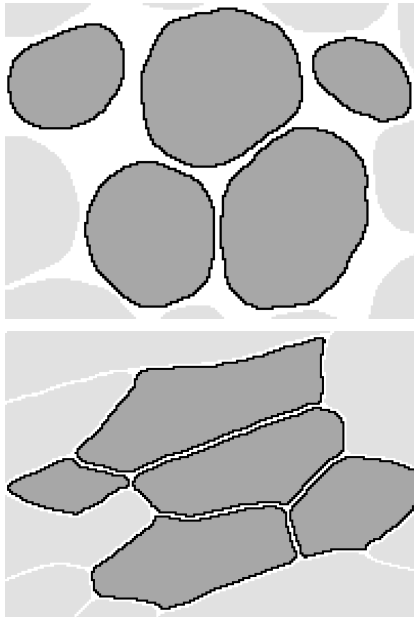
Alle Phasengrenzen =  
gesamte Phasengrenzfläche



Korngrenzen im engen Sinn =  
gesamte Grenzfläche zwischen  
Körnern gleicher Phase



# segments



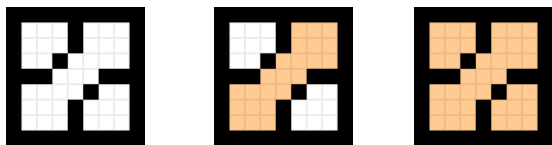
raster / pixels

segments

segment boundaries

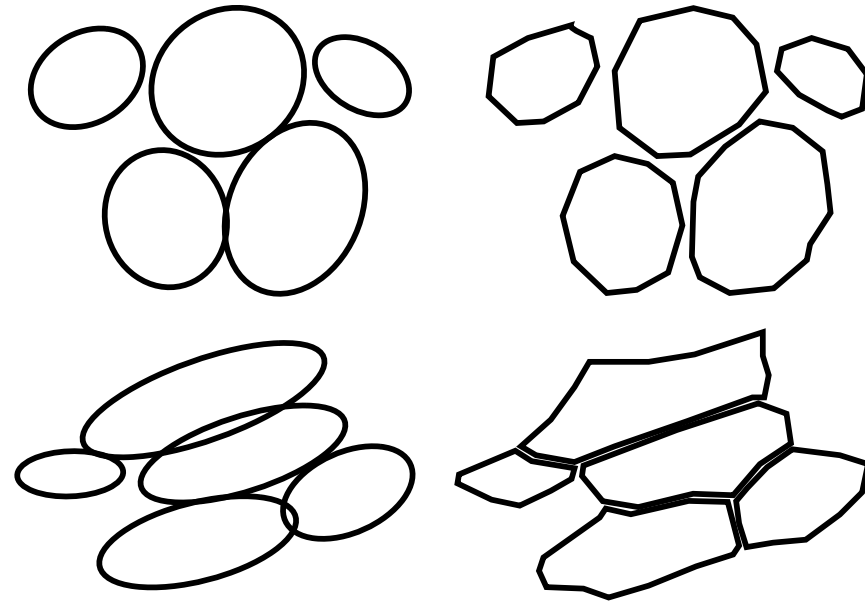
= connected pixels

(4-neighbour, 8-neighbor)



<http://de.wikipedia.org/wiki/Floodfill>

feature extraction:



objects / vectors

best-fit ellipses  
(PCA)

= continuous line  
fitted to shape  
and size of segments

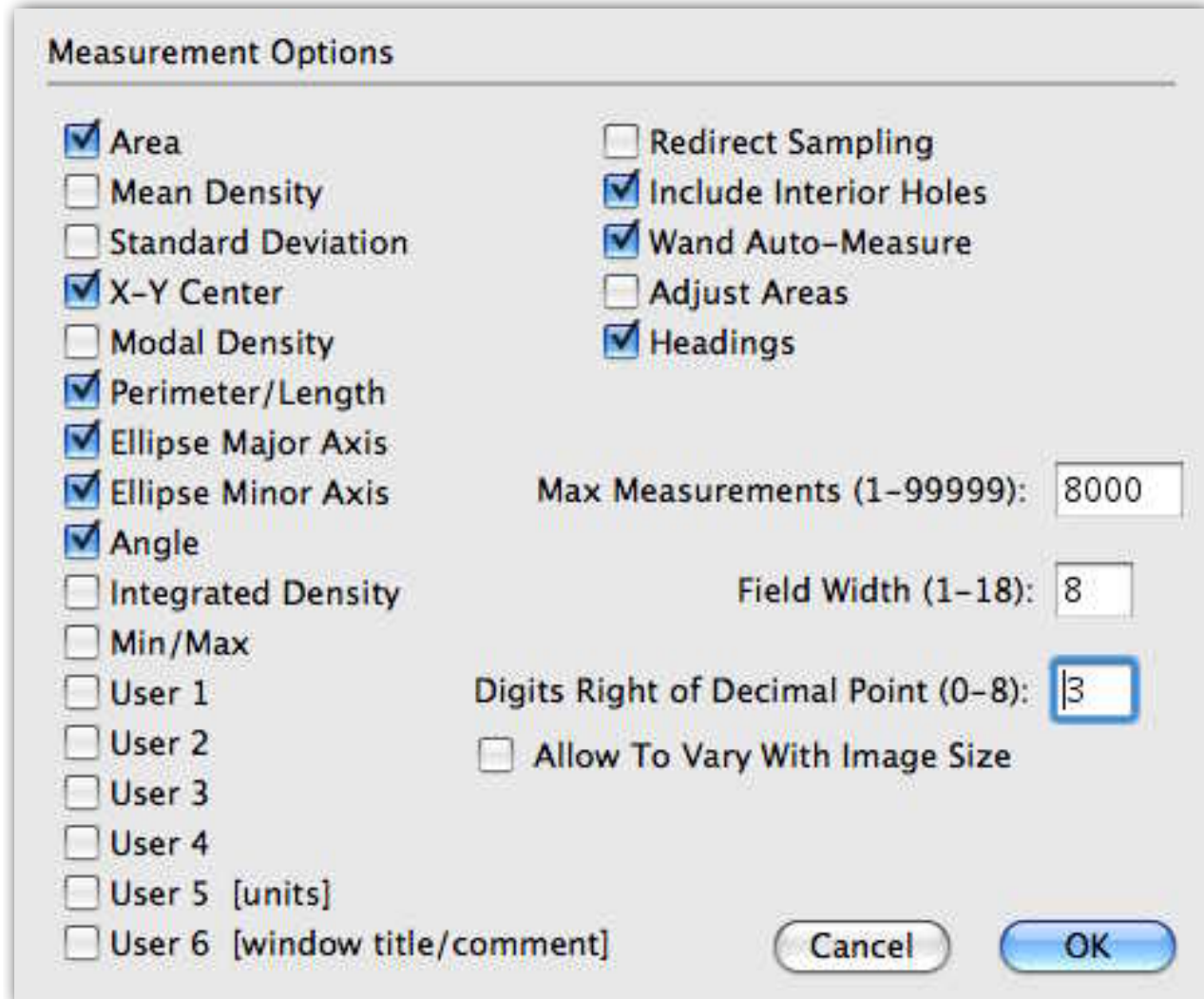
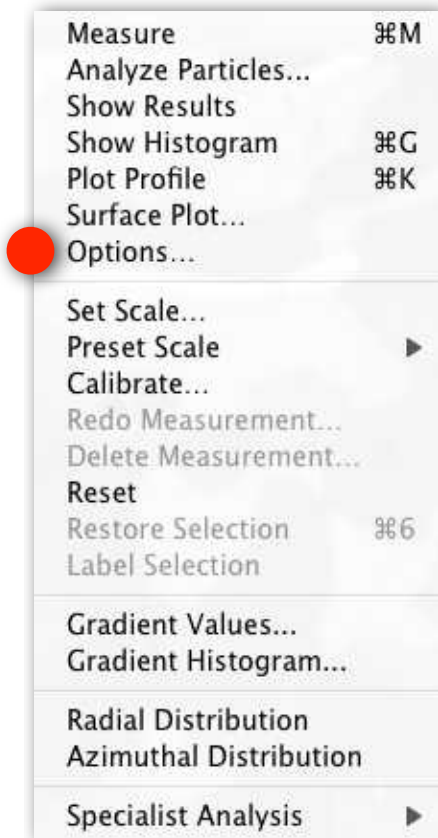
polygonal chains  
(polylines)

= line segments  
(vectors) connecting  
vertex points

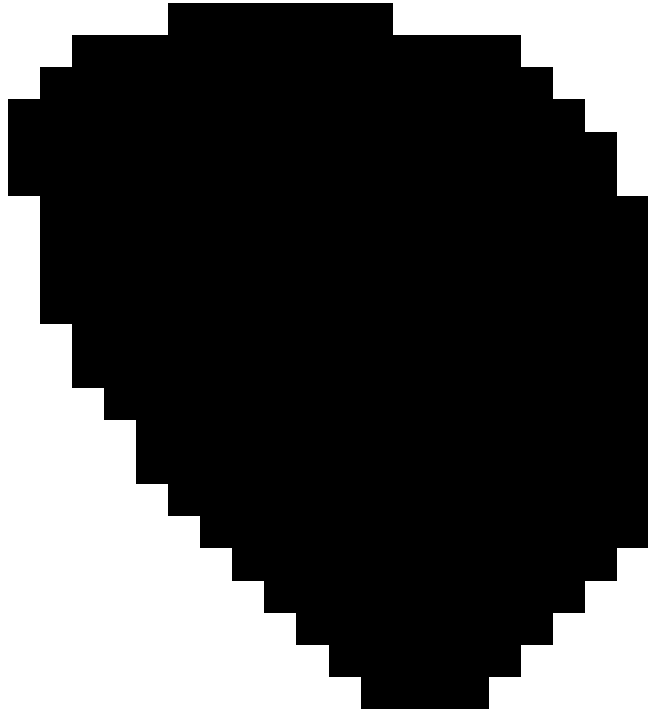
# image analysis

# Image SXM: define measurements

## Image SXM / Analyze menu



# Analyze - segments



Area:

- no. of pixels
- scaled area

**Area:** 76.11 sq  $\mu\text{m}$

**X:** 163.190  $\mu\text{m}$

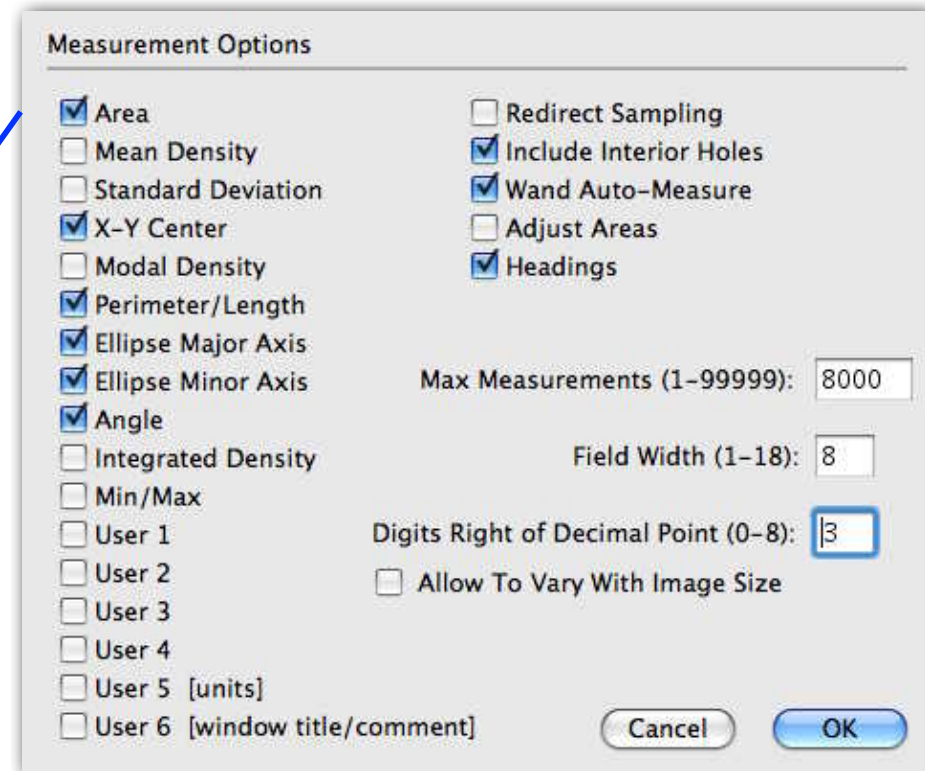
**Y:** 87.585  $\mu\text{m}$

**Len:** 32.815  $\mu\text{m}$

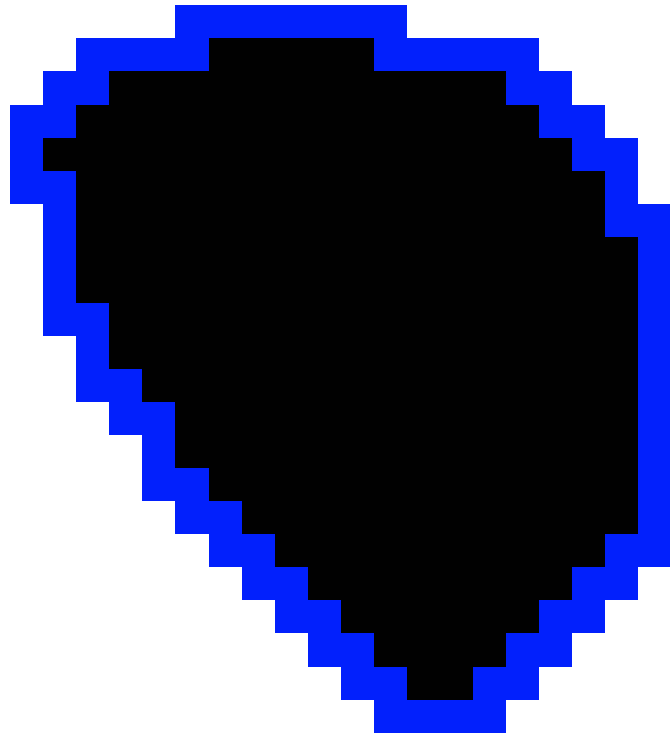
**Major:** 11.422  $\mu\text{m}$

**Minor:** 8.485  $\mu\text{m}$

**Angle:** 125.2°



# Analyze - segments



Area: 76.11 sq  $\mu\text{m}$   
X: 183.196  $\mu\text{m}$   
Y: 97.595  $\mu\text{m}$   
**Len: 32.815  $\mu\text{m}$**   
Major: 11.422  $\mu\text{m}$   
Minor: 8.485  $\mu\text{m}$   
Angle: 125.2°

Perimeter/Length:  
length of perimeter

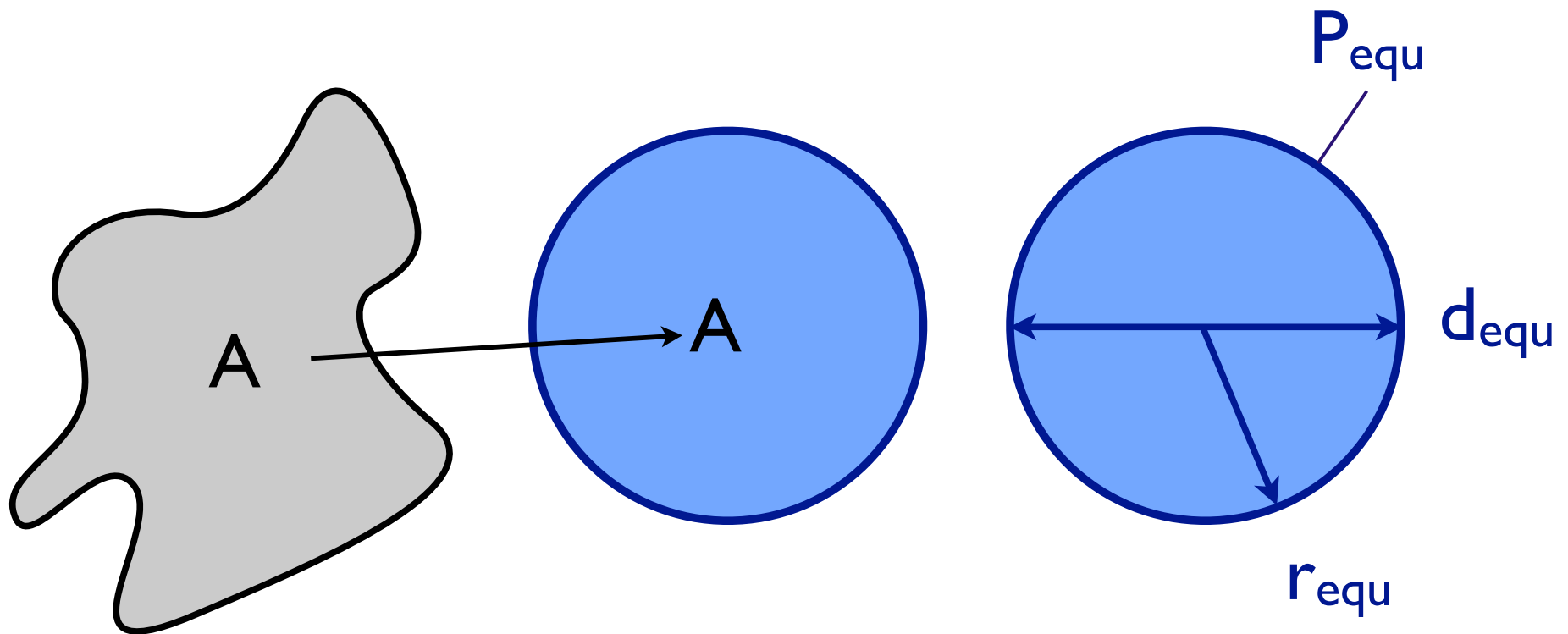
Measurement Options

<input checked="" type="checkbox"/> Area	<input type="checkbox"/> Redirect Sampling
<input type="checkbox"/> Mean Density	<input checked="" type="checkbox"/> Include Interior Holes
<input type="checkbox"/> Standard Deviation	<input checked="" type="checkbox"/> Wand Auto-Measure
<input checked="" type="checkbox"/> X-Y Center	<input type="checkbox"/> Adjust Areas
<input type="checkbox"/> Modal Density	<input checked="" type="checkbox"/> Headings
<input checked="" type="checkbox"/> Perimeter/Length	Max Measurements (1-99999): <input type="text" value="8000"/>
<input checked="" type="checkbox"/> Ellipse Major Axis	Field Width (1-18): <input type="text" value="8"/>
<input checked="" type="checkbox"/> Ellipse Minor Axis	Digits Right of Decimal Point (0-8): <input type="text" value="3"/>
<input checked="" type="checkbox"/> Angle	<input type="checkbox"/> Allow To Vary With Image Size
<input type="checkbox"/> Integrated Density	
<input type="checkbox"/> Min/Max	
<input type="checkbox"/> User 1	
<input type="checkbox"/> User 2	
<input type="checkbox"/> User 3	
<input type="checkbox"/> User 4	
<input type="checkbox"/> User 5 [units]	
<input type="checkbox"/> User 6 [window title/comment]	

Cancel OK



# derived measures



$A$

$r_{\text{equ}}$  (equivalent radius)

$d_{\text{equ}}$  (equivalent diameter)

$P_{\text{equ}}$  (equivalent perimeter)

$= A$

$= \sqrt{A / \pi}$

$= 2 \cdot \sqrt{A / \pi}$

$= 2 \cdot \sqrt{\pi \cdot A}$

# shape descriptors - shape factors

gemessen wird: A, die Fläche und P, der Umfang (Perimeter)

berechnet wird: der Radius  $r_{\text{equ}}$  des Kreises mit der Fläche A und die Fläche  $A_{\text{equ}}$  des Kreises mit dem Umfang P

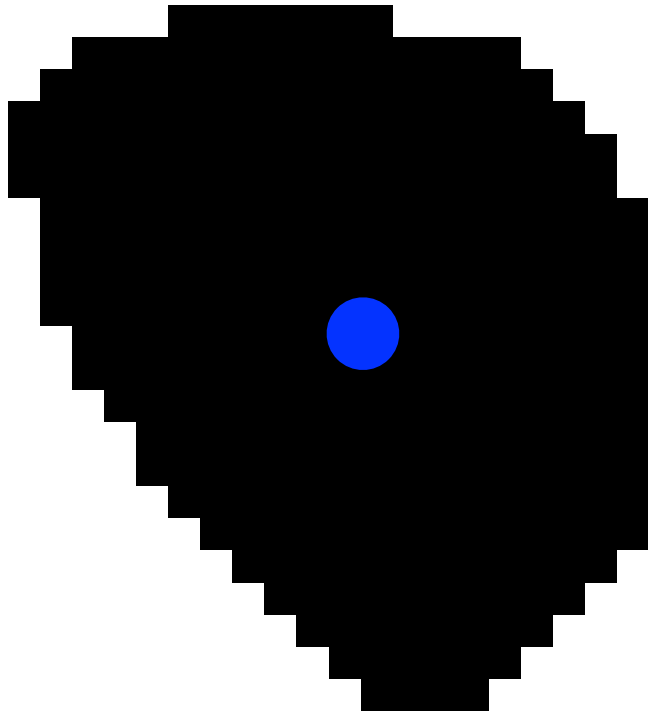
$$r_{\text{equ}} = \sqrt{\frac{A}{\pi}} \quad A_{\text{equ}} = \pi \left( \frac{P}{2\pi} \right)^2 = \frac{P^2}{4\pi}$$

von  $r_{\text{equ}}$  und  $A_{\text{equ}}$  werden zwei Formfaktoren abgeleitet:

$$SF_1 = \frac{P}{P_{\text{equ}}} \rightarrow SF_1 = \frac{P}{2\sqrt{\pi A}}$$

$$SF_2 = \frac{A}{A_{\text{equ}}} \rightarrow SF_2 = \frac{4\pi A}{P^2}$$

# Analyze - best-fit ellipse



X-Y Center:  
center of gravity

Area: 76.11 sq.  $\mu\text{m}$

X: 183.196  $\mu\text{m}$

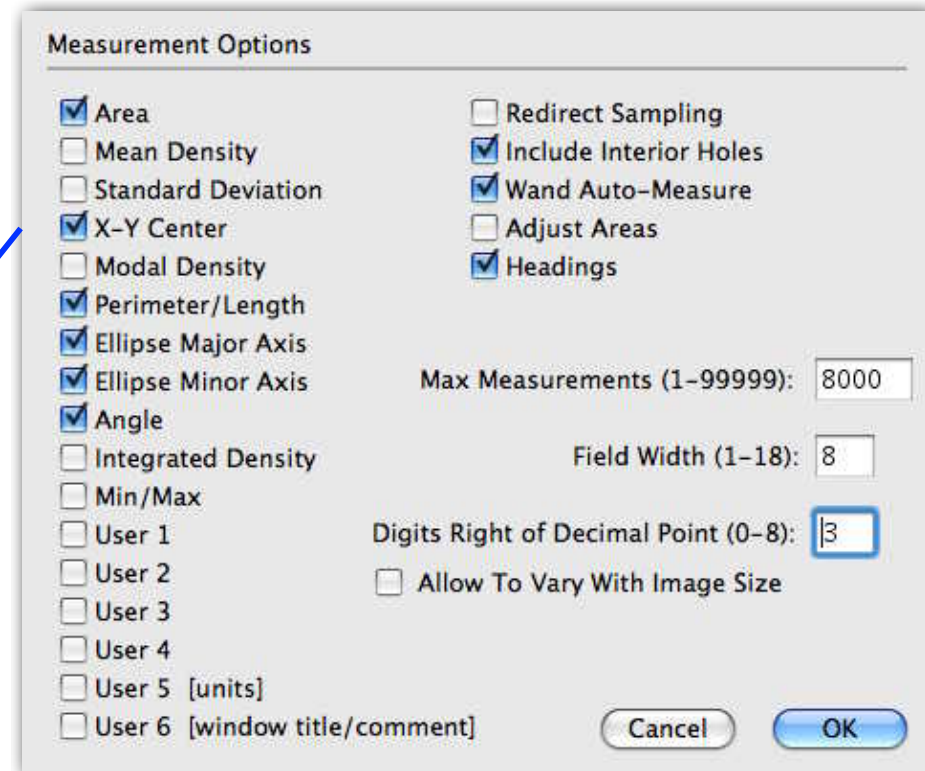
Y: 87.585  $\mu\text{m}$

Len: 32.815  $\mu\text{m}$

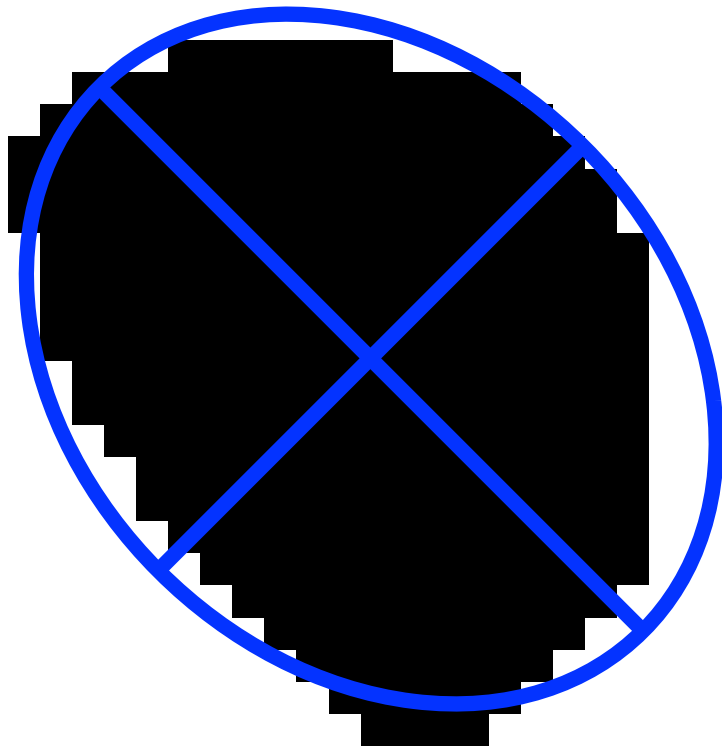
Major: 11.422  $\mu\text{m}$

Minor: 8.485  $\mu\text{m}$

Angle: 125.2°

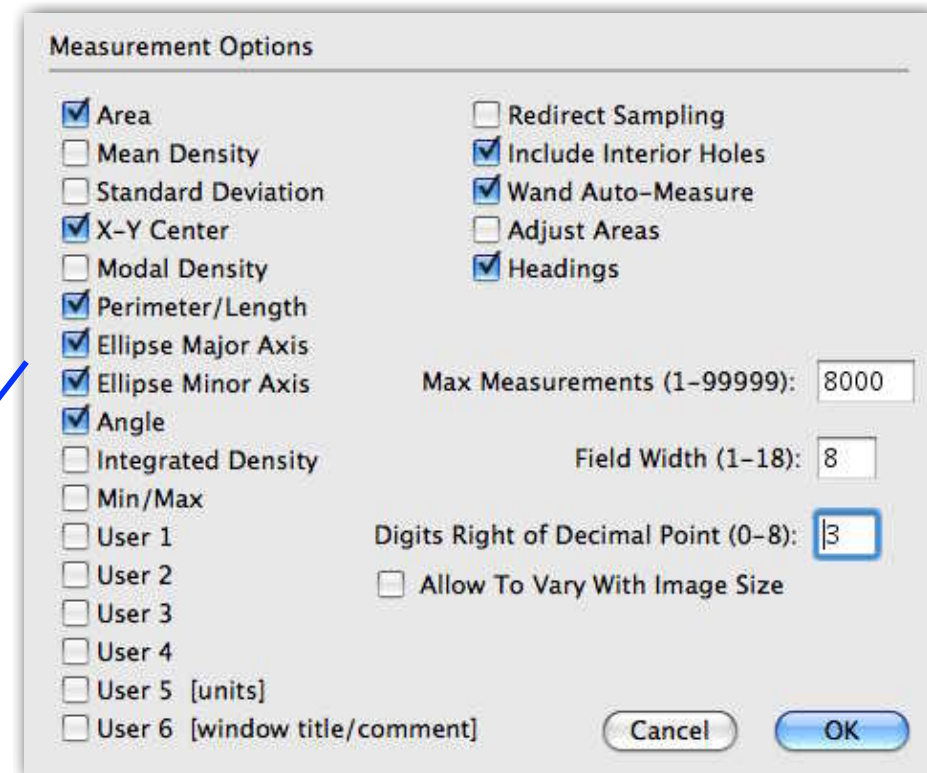


# Analyze - best-fit ellipse

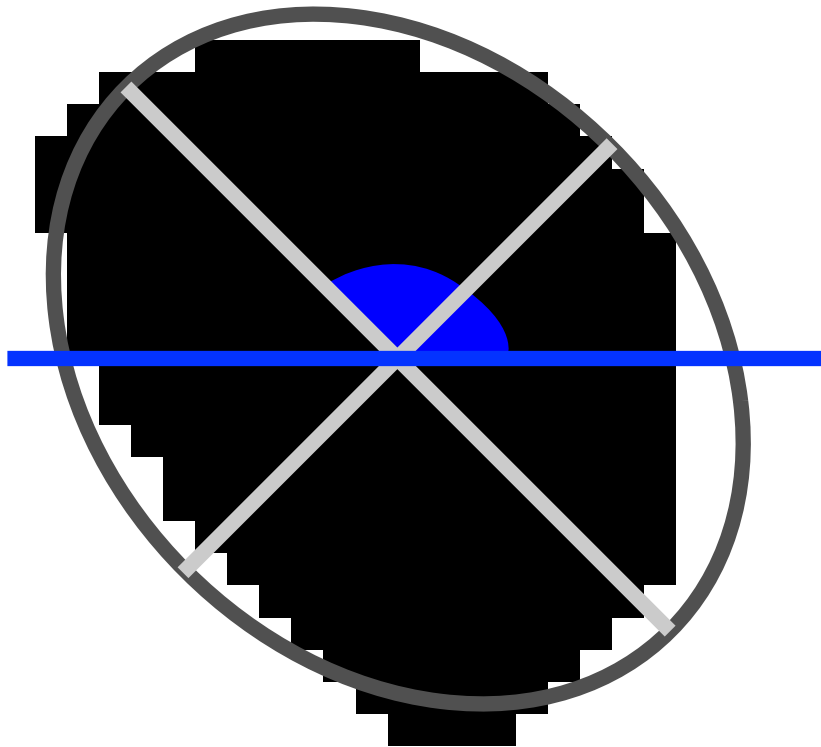


Ellipse Major Axis  
Ellipse Minor Axis  
long and short diameter of ellipse

Area: 76.11 sq  $\mu\text{m}$   
X: 183.196  $\mu\text{m}$   
Y: 87.585  $\mu\text{m}$   
Len: 32.815  $\mu\text{m}$   
**Major: 11.422  $\mu\text{m}$**   
**Minor: 8.485  $\mu\text{m}$**   
Angle: 123.2



# Analyze - best-fit ellipse



Area: 76.11 sq  $\mu\text{m}$   
X: 183.196  $\mu\text{m}$   
Y: 87.585  $\mu\text{m}$   
Len: 32.815  $\mu\text{m}$   
Majr: 11.422  $\mu\text{m}$   
Minr: 8.485  $\mu\text{m}$

Angle: 125.2°

Angle:  
Angle of long axis w/r to positive  
x-axis (measured CCLW)

Measurement Options

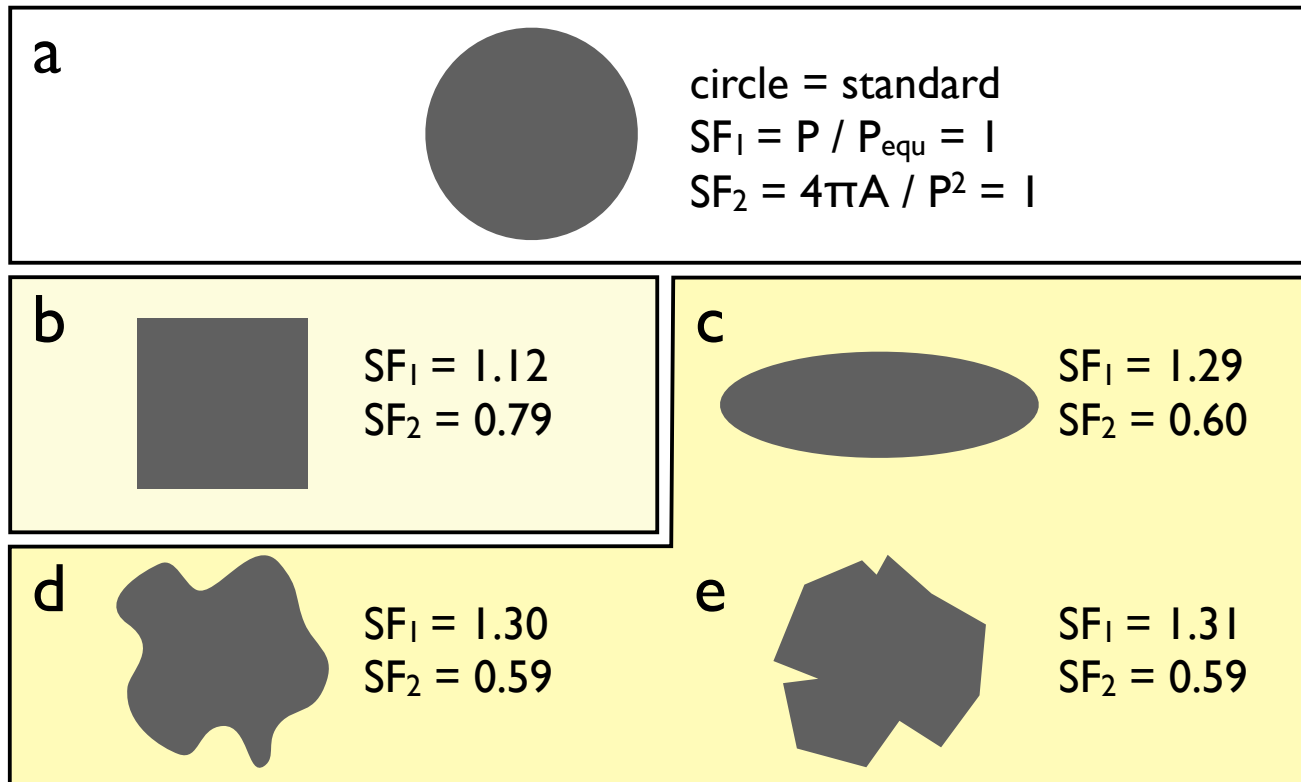
<input checked="" type="checkbox"/> Area	<input type="checkbox"/> Redirect Sampling
<input type="checkbox"/> Mean Density	<input checked="" type="checkbox"/> Include Interior Holes
<input type="checkbox"/> Standard Deviation	<input checked="" type="checkbox"/> Wand Auto-Measure
<input checked="" type="checkbox"/> X-Y Center	<input type="checkbox"/> Adjust Areas
<input type="checkbox"/> Modal Density	<input checked="" type="checkbox"/> Headings
<input checked="" type="checkbox"/> Perimeter/Length	Max Measurements (1-99999): <input type="text" value="8000"/>
<input checked="" type="checkbox"/> Ellipse Major Axis	Field Width (1-18): <input type="text" value="8"/>
<input checked="" type="checkbox"/> Ellipse Minor Axis	Digits Right of Decimal Point (0-8): <input type="text" value="3"/>
<input checked="" type="checkbox"/> Angle	<input type="checkbox"/> Allow To Vary With Image Size
<input type="checkbox"/> Integrated Density	
<input type="checkbox"/> Min/Max	
<input type="checkbox"/> User 1	
<input type="checkbox"/> User 2	
<input type="checkbox"/> User 3	
<input type="checkbox"/> User 4	
<input type="checkbox"/> User 5 [units]	
<input type="checkbox"/> User 6 [window title/comment]	

Cancel OK

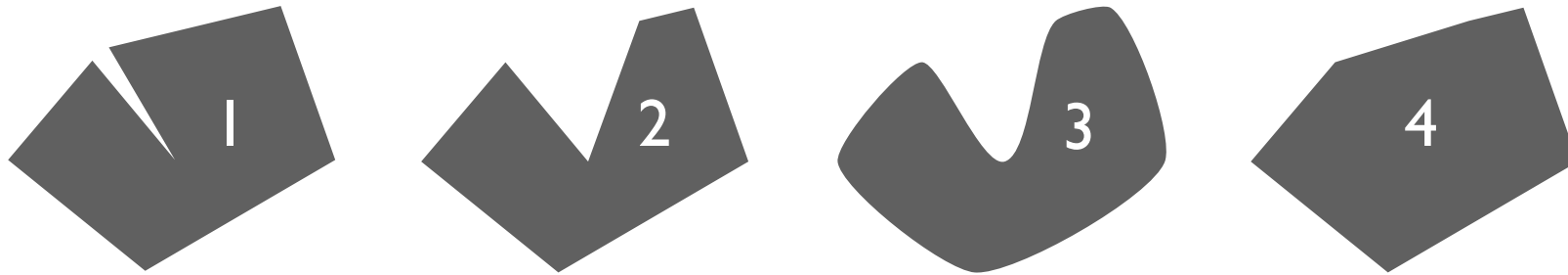


# shape descriptors - shape factors

- $r_{\text{equ}}, a, b,$  size (linear)  
 $b / a \leq 1$  axial ratio, flattening, ..  
 $a / b \geq 1$  aspect ratio, elongation, ...  
 $P / P_{\text{equ}} \geq 1$  circularity, sphericity, lobateness, angularity, convexity, ...  
("fractal dimension")



# Bedeutung von Formfaktoren



#	SF <sub>1</sub>	SF <sub>2</sub>	a / b shape	a / b rectangle	a / b ellipse
1	1.48	0.46	1.5	4.6	4.9
2	1.48	0.46	1.7	4.6	4.9
3	1.41	0.50	1.6	4.0	4.4
4	1.18	0.72	1.4	1.9	2.7



rectangles and ellipses with same shape factors as shapes 1 to 4

**example**

# example: quartz

The image shows a software interface for particle analysis. On the left, a menu is open over a grayscale image of quartz particles. The menu items are: Measure (⌘M), Analyze Particles..., Show Results, Show Histogram (⌘G), Plot Profile (⌘K), Surface Plot..., Options..., Set Scale... to pixel (highlighted with a red circle), Preset Scale, Calibrate..., Redo Measurement..., Delete Measurement..., Reset, Restore Selection (⌘6), Label Selection, Gradient Values..., Gradient Histogram..., Radial Distribution, Azimuthal Distribution, and Specialist Analysis. On the right, the 'Measurement Options' dialog box is open, showing various settings for the analysis. The 'Area' checkbox is checked. Other checked options include 'X-Y Center', 'Perimeter/Length', 'Ellipse Major Axis', 'Ellipse Minor Axis', 'Angle', 'Include Interior Holes', 'Wand Auto-Measure', and 'Headings'. The 'Max Measurements' field is set to 8000, 'Field Width' to 8, and 'Digits Right of Decimal Point' to 3. The 'Allow To Vary With Image Size' checkbox is unchecked. The dialog has 'Cancel' and 'OK' buttons.

Measurement Options

- Area
- Mean Density
- Standard Deviation
- X-Y Center
- Modal Density
- Perimeter/Length
- Ellipse Major Axis
- Ellipse Minor Axis
- Angle
- Integrated Density
- Min/Max
- User 1
- User 2
- User 3
- User 4
- User 5 [units]
- User 6 [window title/comment]
- Redirect Sampling
- Include Interior Holes
- Wand Auto-Measure
- Adjust Areas
- Headings

Max Measurements (1-99999): 8000

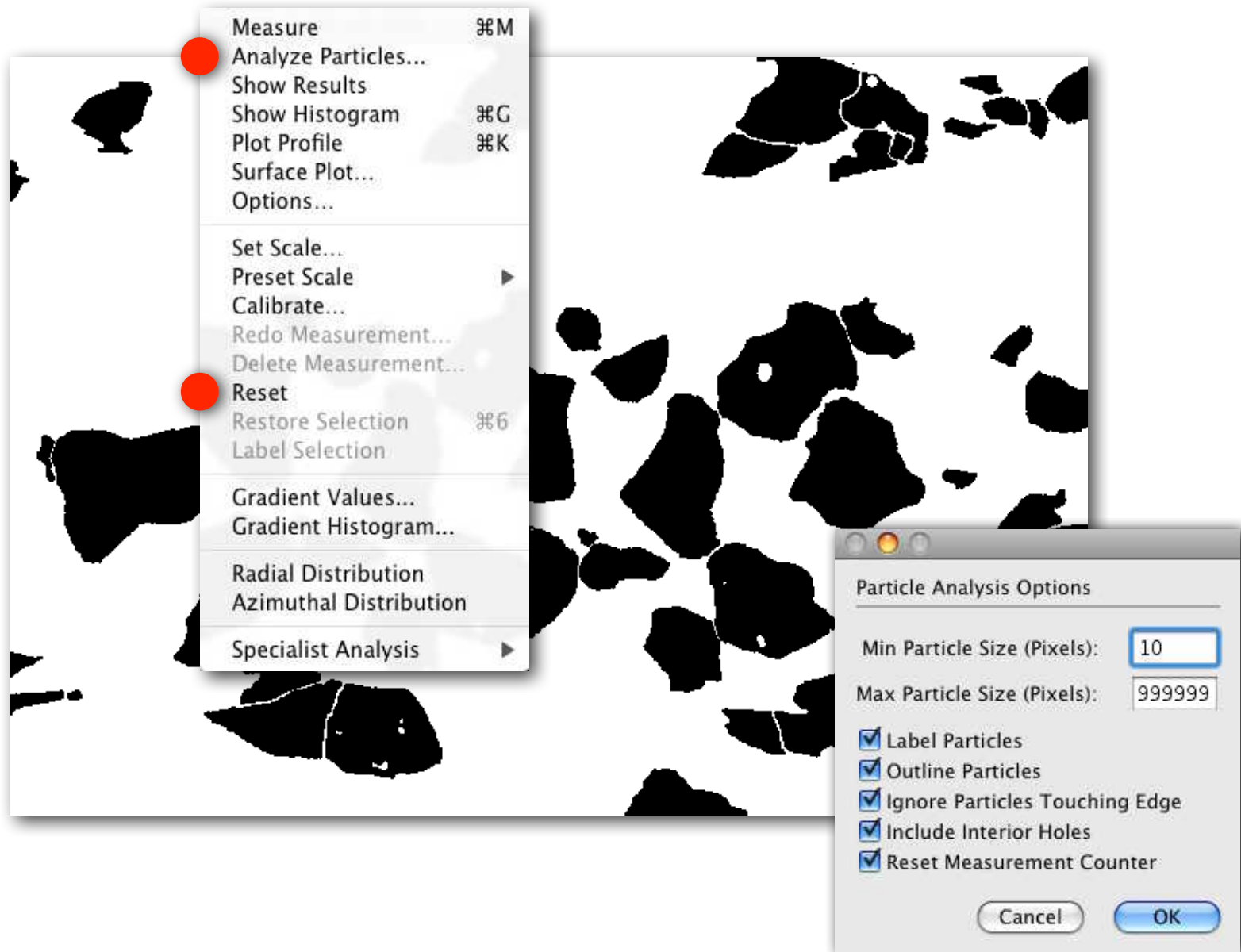
Field Width (1-18): 8

Digits Right of Decimal Point (0-8): 3

Allow To Vary With Image Size

Cancel OK

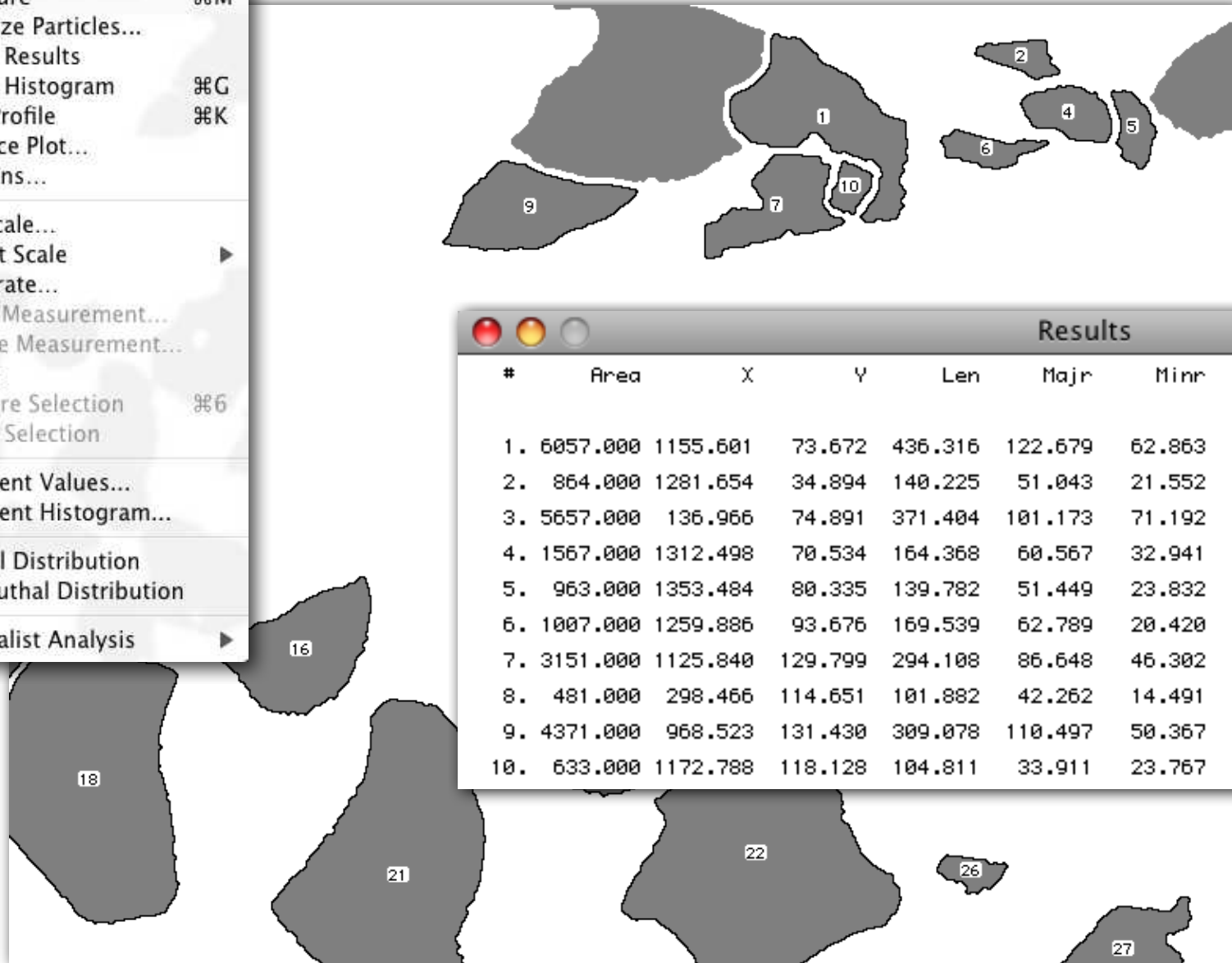
# example: quartz





# example: quartz

- Measure ⌘M
- Analyze Particles...
- Show Results
- Show Histogram ⌘G
- Plot Profile ⌘K
- Surface Plot...
- Options...
- Set Scale...
- Preset Scale
- Calibrate...
- Redo Measurement...
- Delete Measurement...
- Reset
- Restore Selection ⌘6
- Label Selection
- Gradient Values...
- Gradient Histogram...
- Radial Distribution
- Azimuthal Distribution
- Specialist Analysis



Results							
#	Area	X	Y	Len	Majr	Minr	Angle
1.	6057.000	1155.601	73.672	436.316	122.679	62.863	144.4
2.	864.000	1281.654	34.894	140.225	51.043	21.552	167.9
3.	5657.000	136.966	74.891	371.404	101.173	71.192	44.0
4.	1567.000	1312.498	70.534	164.368	60.567	32.941	164.7
5.	963.000	1353.484	80.335	139.782	51.449	23.832	102.1
6.	1007.000	1259.886	93.676	169.539	62.789	20.420	176.3
7.	3151.000	1125.840	129.799	294.108	86.648	46.302	31.2
8.	481.000	298.466	114.651	101.882	42.262	14.491	32.9
9.	4371.000	968.523	131.430	309.078	110.497	50.367	7.9
10.	633.000	1172.788	118.128	104.811	33.911	23.767	68.2

# example: quartz

- New ⌘N
- Open... ⌘O
- Browse... ⌘B
- Import...
- Close... ⌘W
- Save ⌘S
- Save As...
- Export...
- Record Preferences
- Revert to Saved
- Duplicate ⌘D
- Get Info ⌘I
- Acquire >
- Export >
- Page Setup...
- Print Image... ⌘P

Save As: TruzzoHighMagNoSc100.tif (Meas)

Macintosh HD

Format: Measurement Values

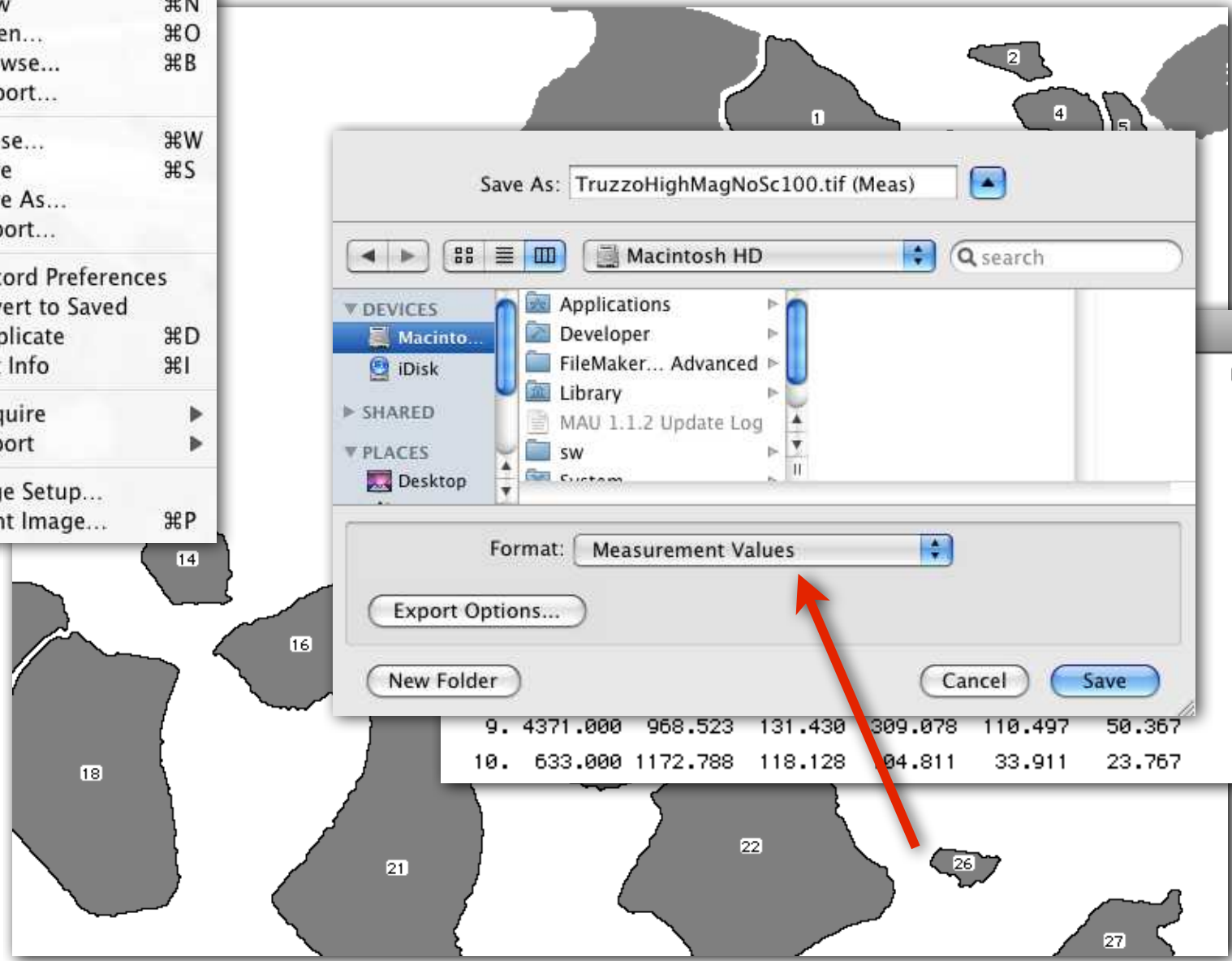
Export Options...

New Folder

Cancel Save

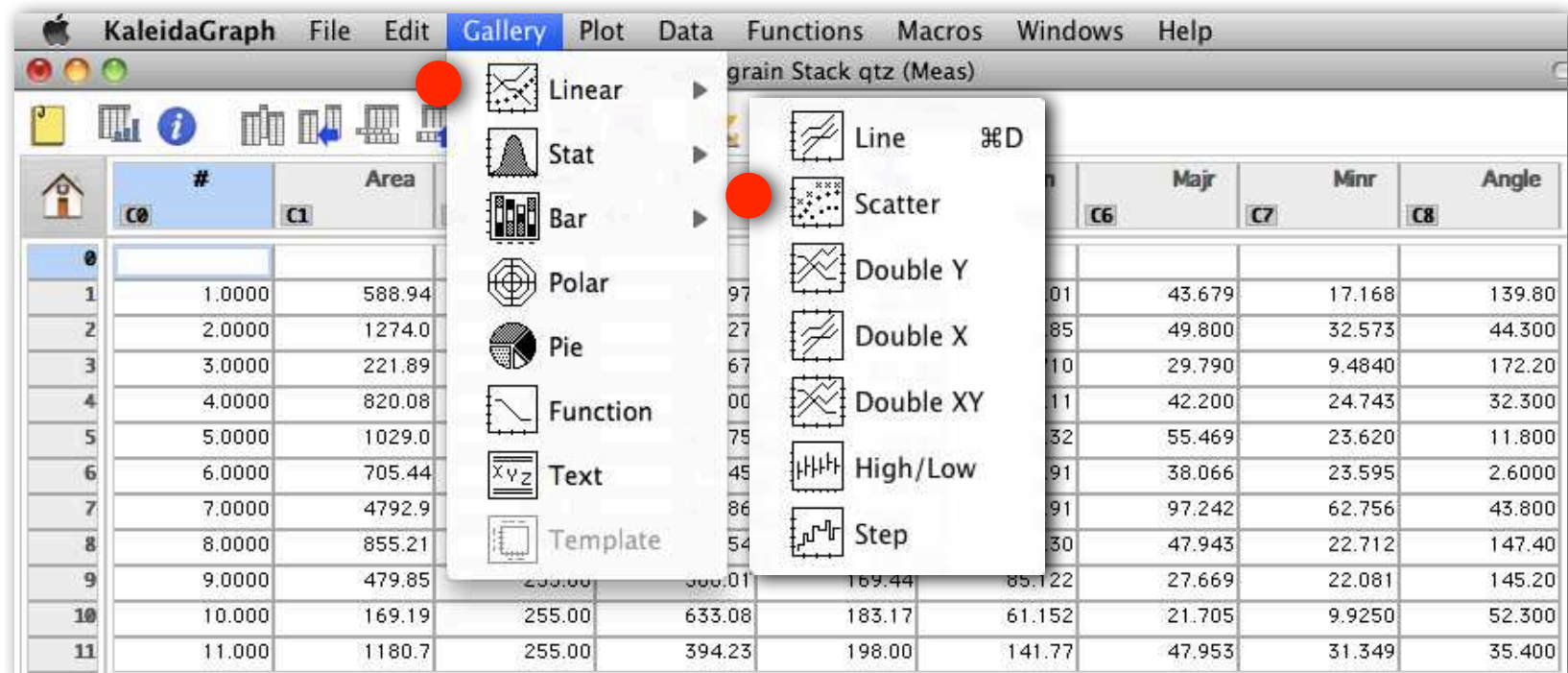
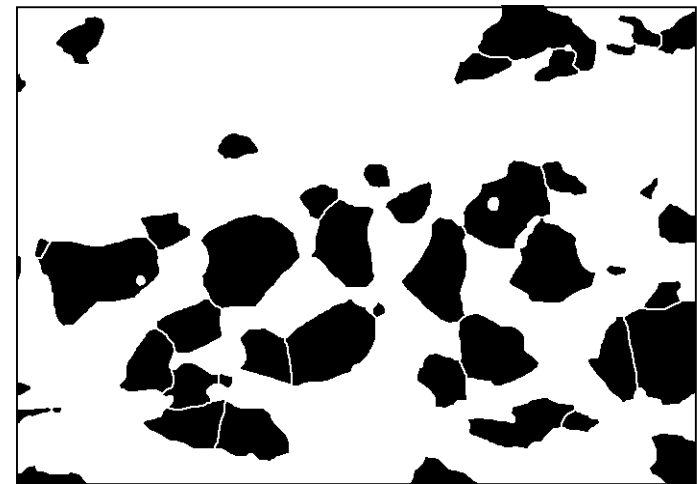
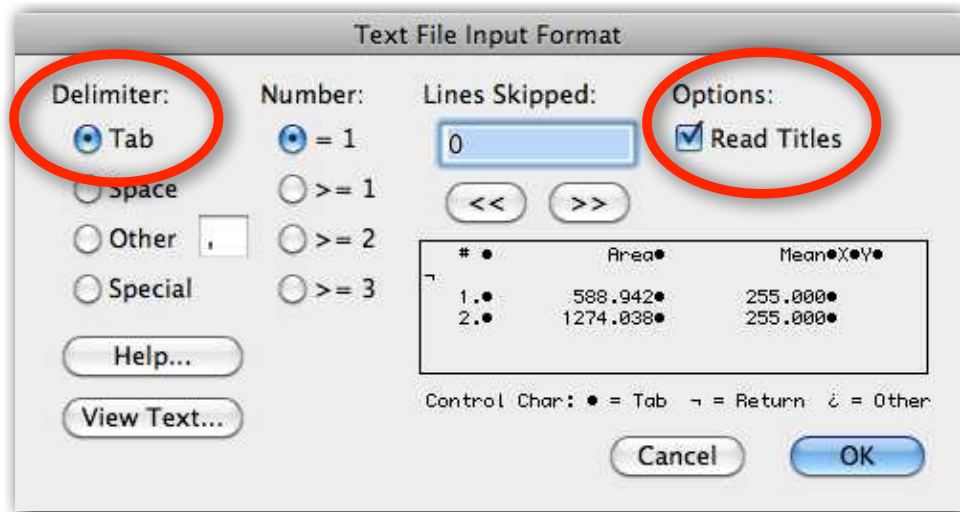
9.	4371.000	968.523	131.430	309.078	110.497	50.367
10.	633.000	1172.788	118.128	94.811	33.911	23.767

Angle
144.4
167.9
44.0
164.7
102.1
176.3
31.2
32.9
7.9
68.2



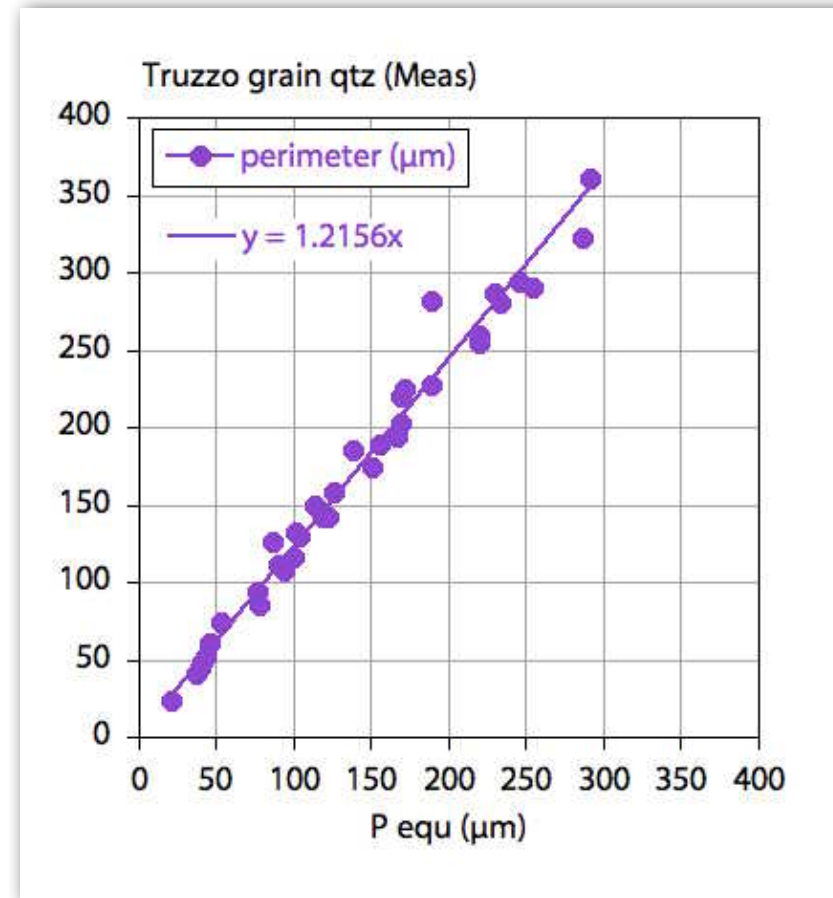
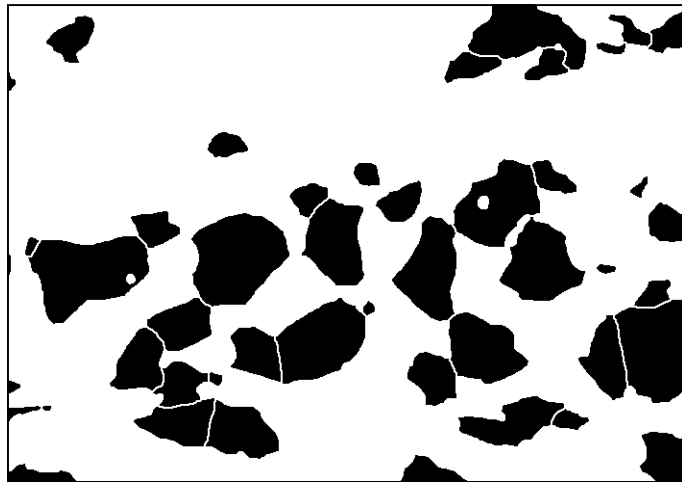
plotting results

# using Kaleidagraph



# from segment boundary - $P / P_{equ}$

type 2 image analysis

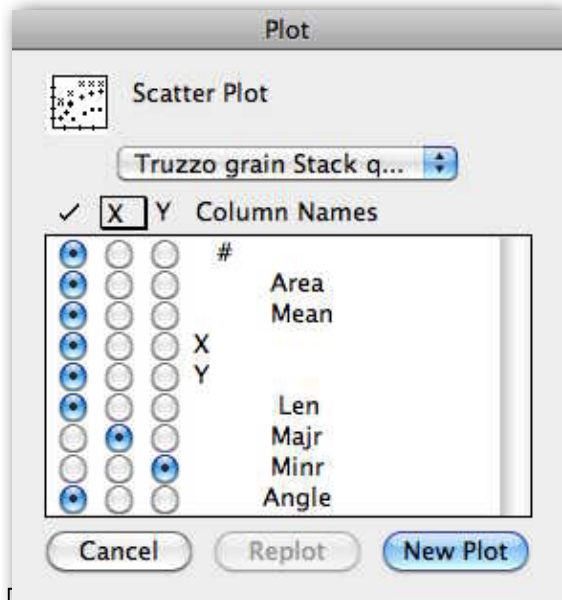


fractal dimension: 1.2156

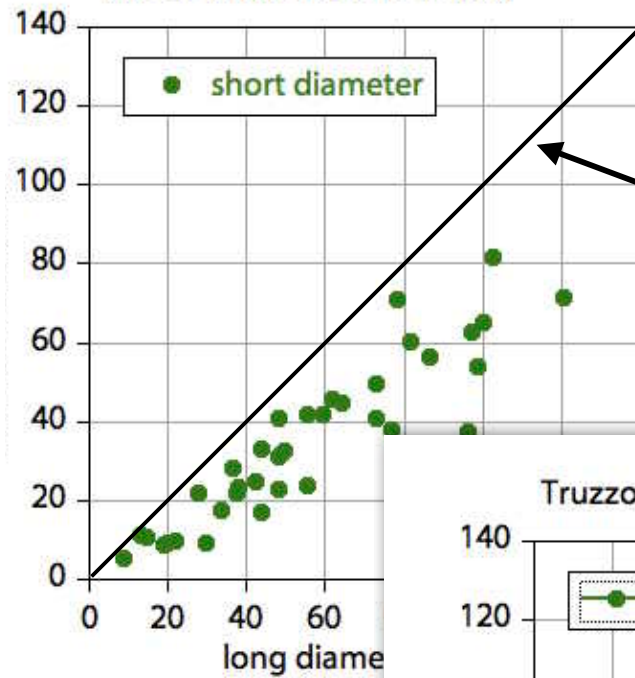


# from best-fit ellipse - axial ratio b/a

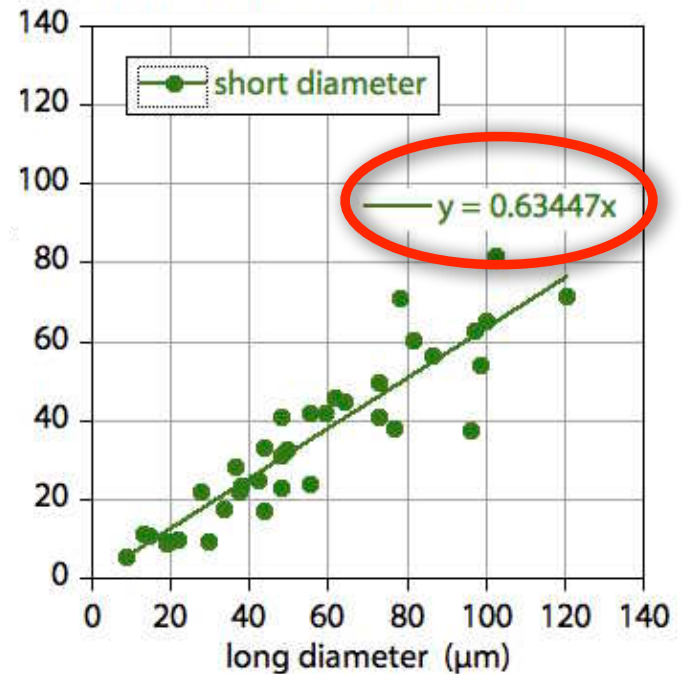
type 3 image analysis



Truzzo grain Stack qtz (Meas)



Truzzo grain Stack qtz (Meas)



# from best-fit ellipse - axial ratio b/a

type 3 image analysis

The screenshot displays a software interface for image analysis. The main window shows a data table with columns for various parameters. A 'Statistics' window is open, showing the mean of the axial ratio b/a as 0.62592. A 'Formula Entry' window is also open, showing the formula  $c8=c7/c6$ .

#	area ( $\mu\text{m}^2$ )	mean density	X	Y	perimeter ( $\mu\text{m}$ )	long diameter ( $\mu\text{m}$ )	short diameter ( $\mu\text{m}$ )	b/a	angle
1	588.94	255.00	624.97	27.008	126.01	43.679	17.168	0.39305	139.80
2	1274.0	255.00	65.027	33.870	157.85	49.800	32.573	0.65408	44.300
3	221.89	255.00	604.67	43.890	74.710	29.790	9.4840	0.31836	172.20
4	820.08	255.00	541.00	60.737	132.11	42.200	24.743	0.58633	32.300
5	1029.0	255.00	463.75	62.056	199.67	77.403	30.300		
6	705.44	255.00	219.45	140.43	173.59	65.316	99.300		
					169.44	183.17	198.00		
					193.22	115.7	237.54	259.4	142.4
					223.45	253.07	321.80	102.43	81.514
								0.79578	43.400

**Statistics**

	b/a
Minimum	0.31836
Maximum	0.90761
Sum	22.533
Points	36
Mean	0.62592
Median	0.64719
RMS	0.64225
Std Deviation	0.14593
Variance	0.021296
Std Error	0.024322
Skewness	-0.1501
Kurtosis	-0.75244

**Formula Entry**

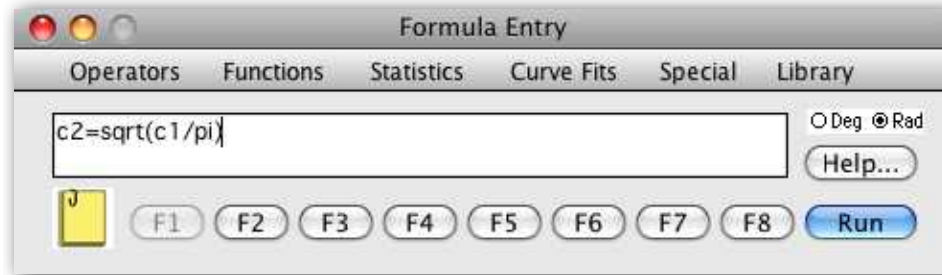
$c8=c7/c6$

**$c8=c7/c6$**

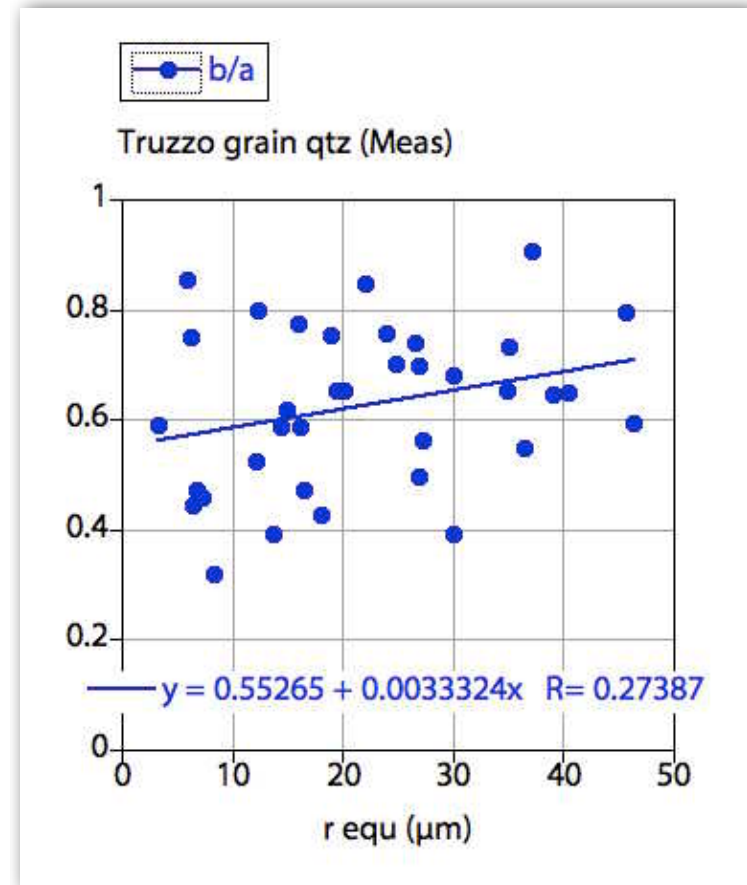
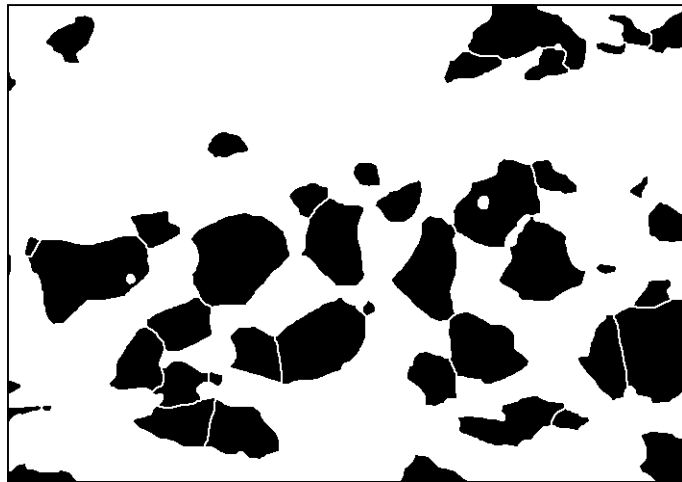
slope of b vs. a: 0.63447

mean of b/a: 0.62565

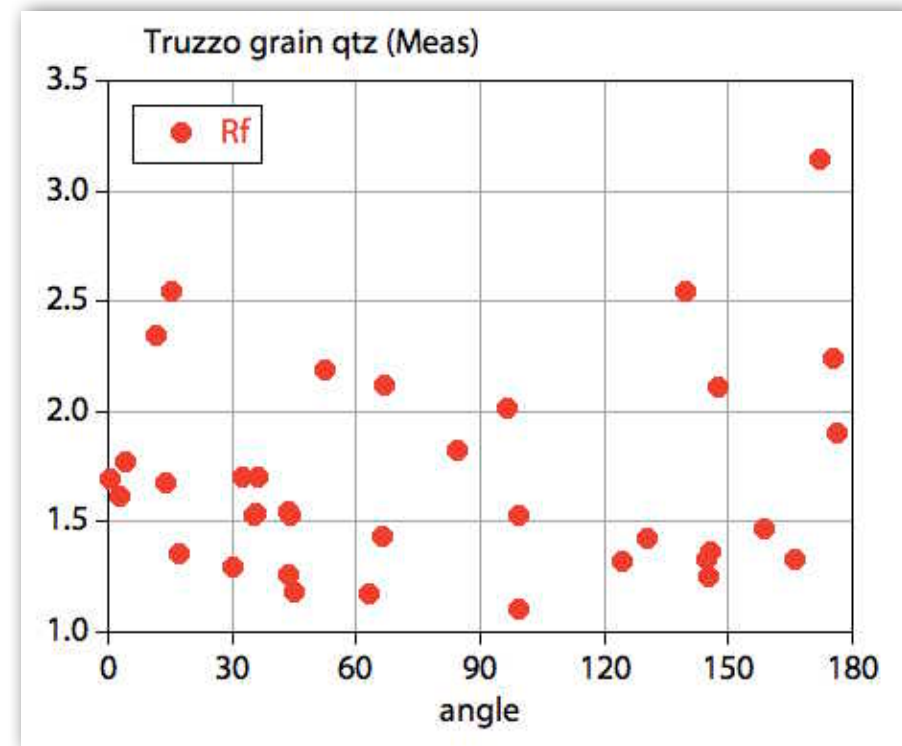
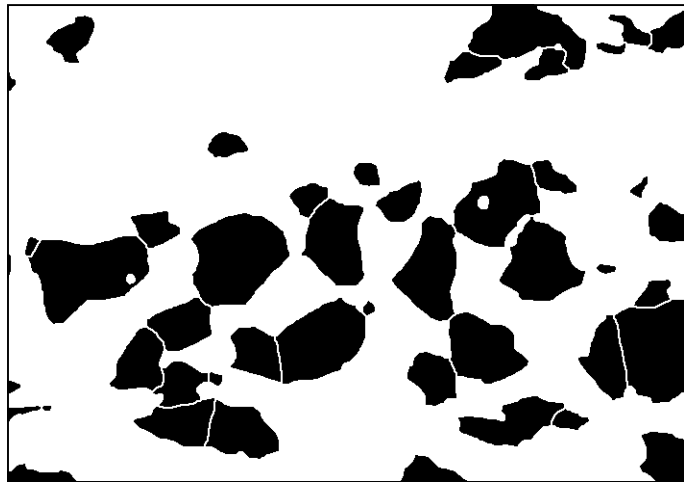
# size dependence - $b/a$ as $f(r_{equ})$



$$c2 = \sqrt{c1/\pi}$$

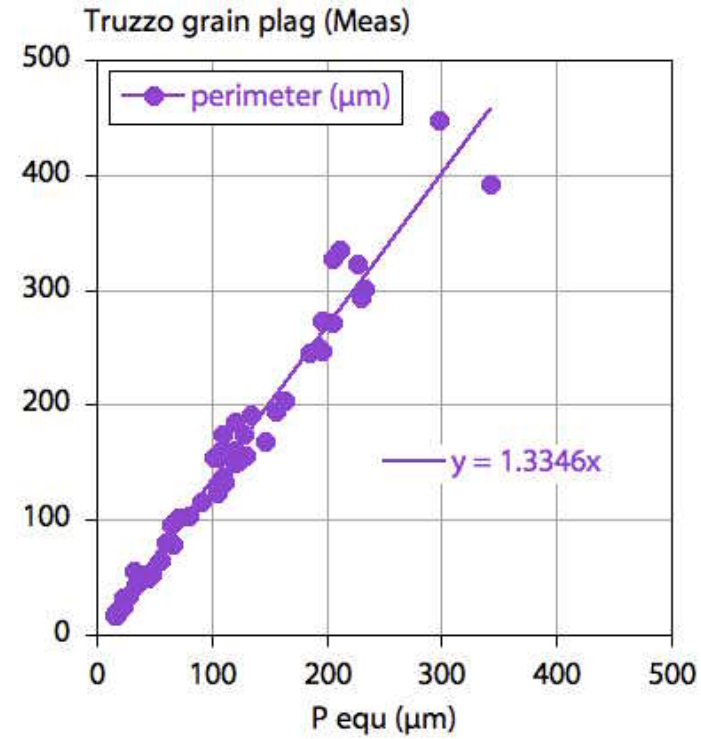
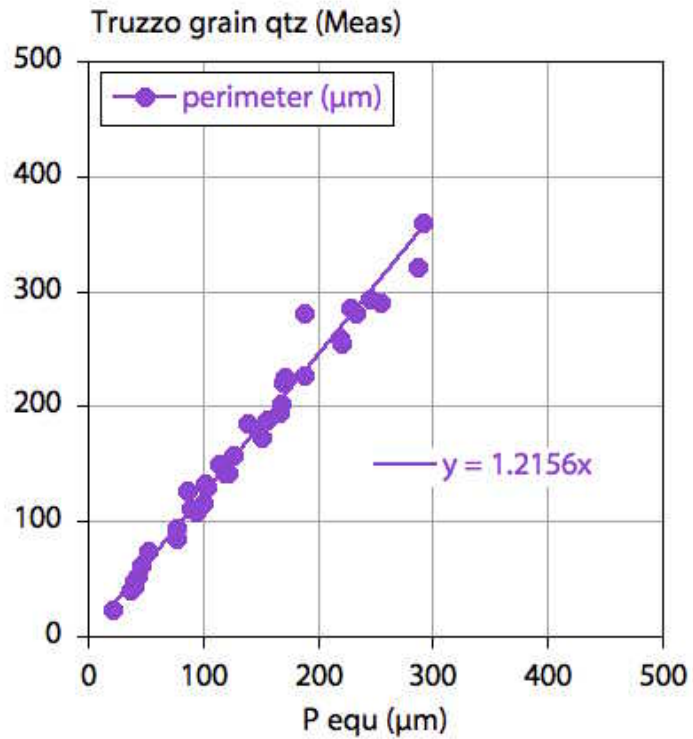
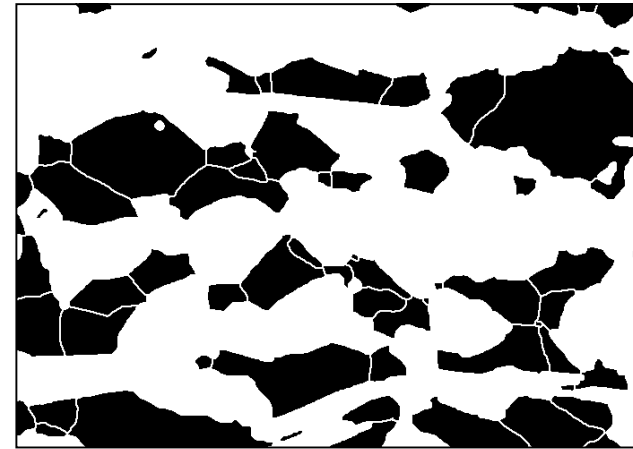
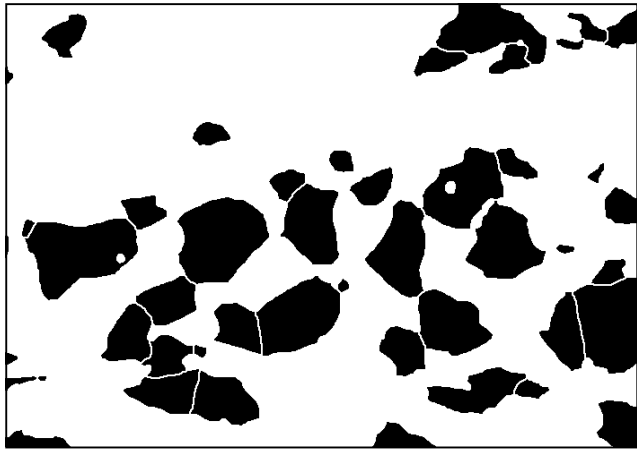


# shape alignment - a/b as $f(\varphi)$



$R_f - \varphi$  diagram

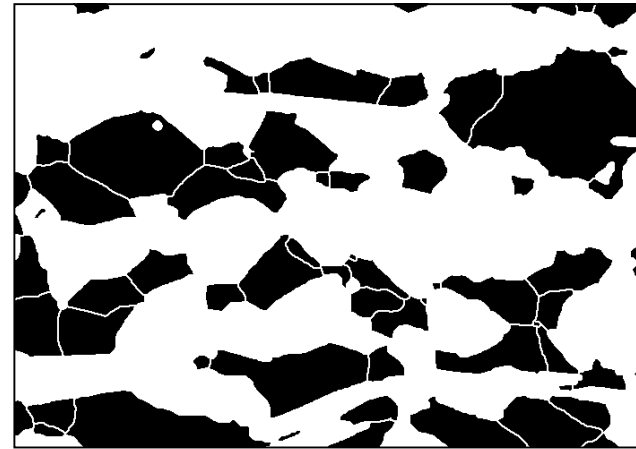
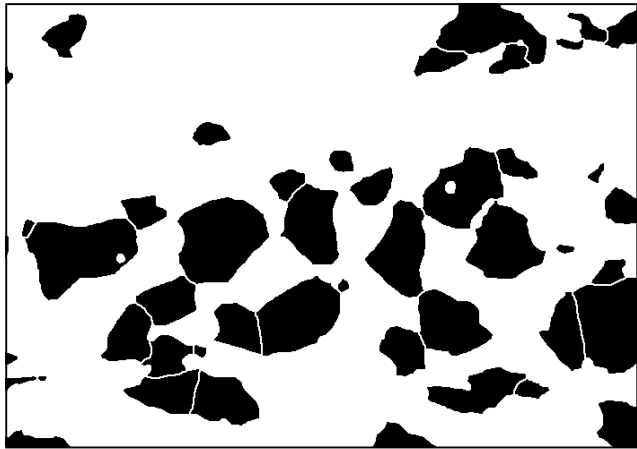
# comparison: quartz - plagioclase



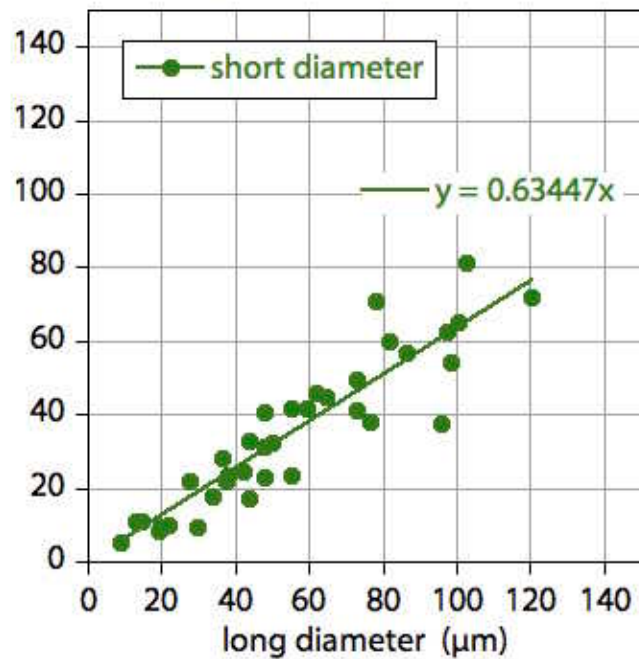
$P/P_{\text{equ}}$



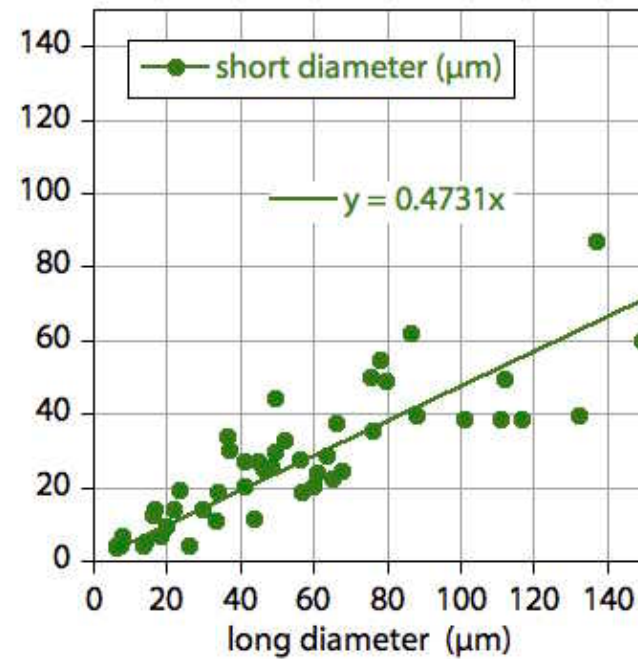
# comparison: quartz - plagioclase



Truzzo grain Stack qtz (Meas)

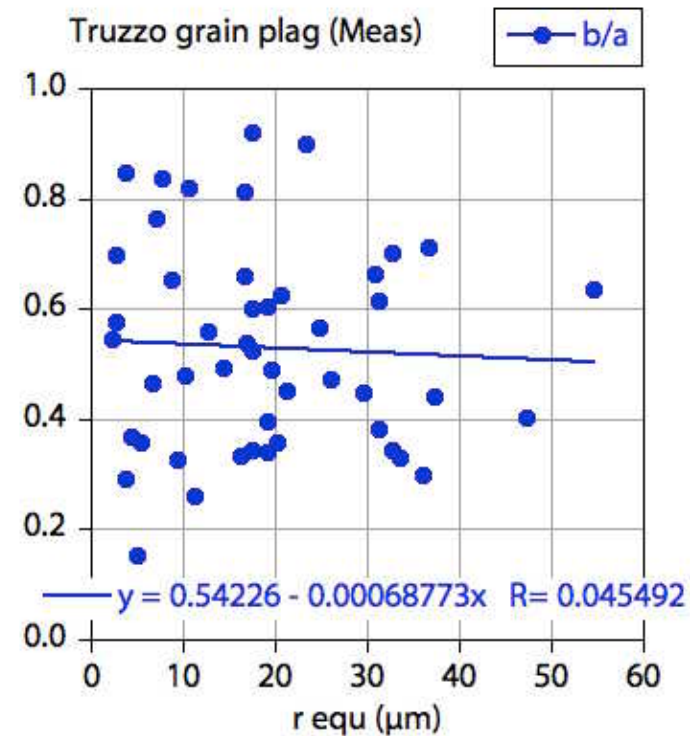
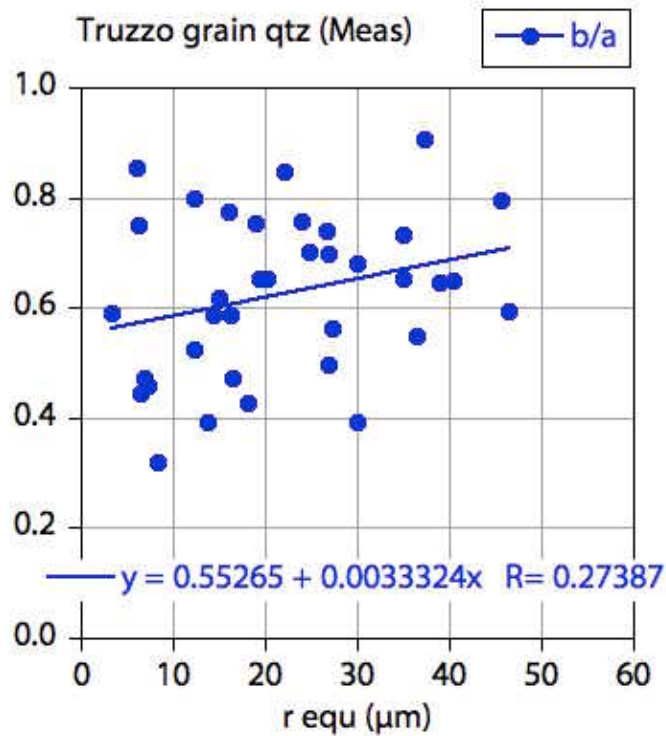
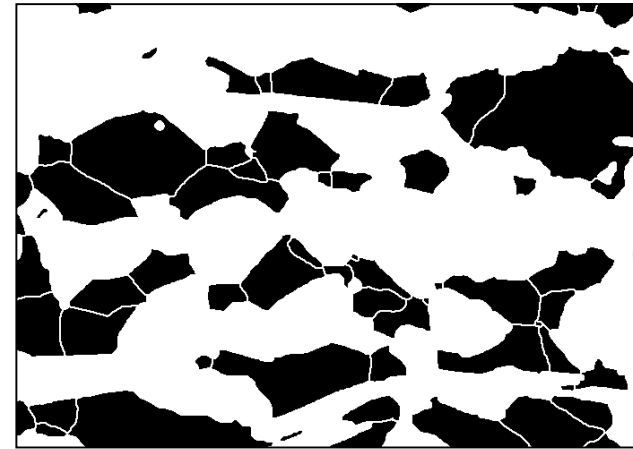
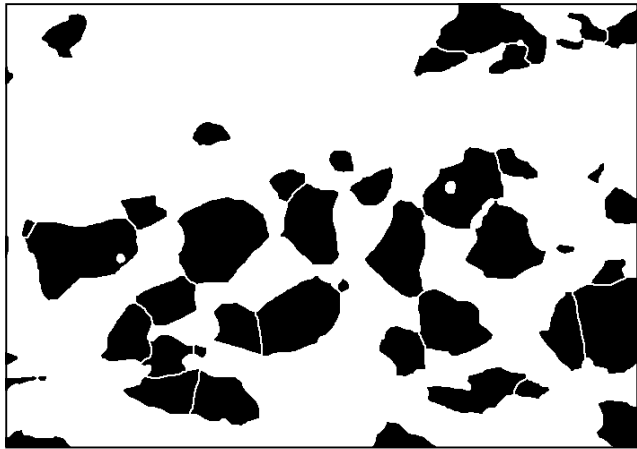


Truzzo grain plag (Meas)



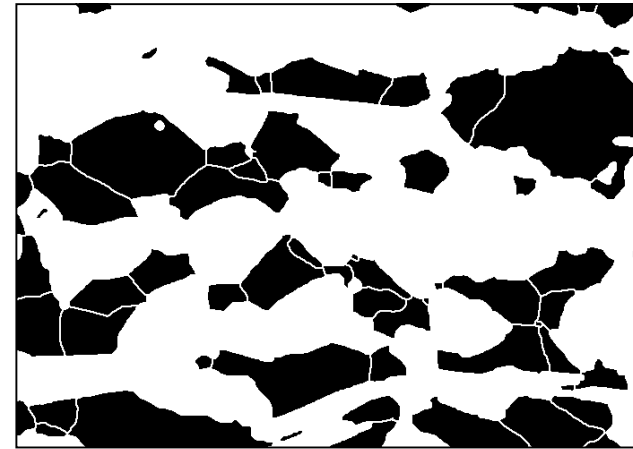
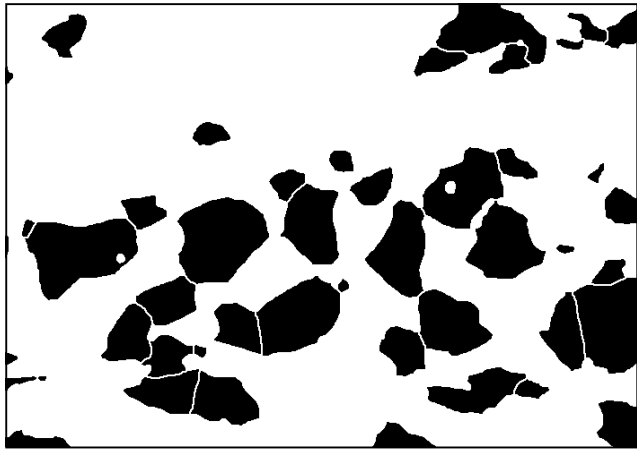
b/a

# comparison: quartz - plagioclase

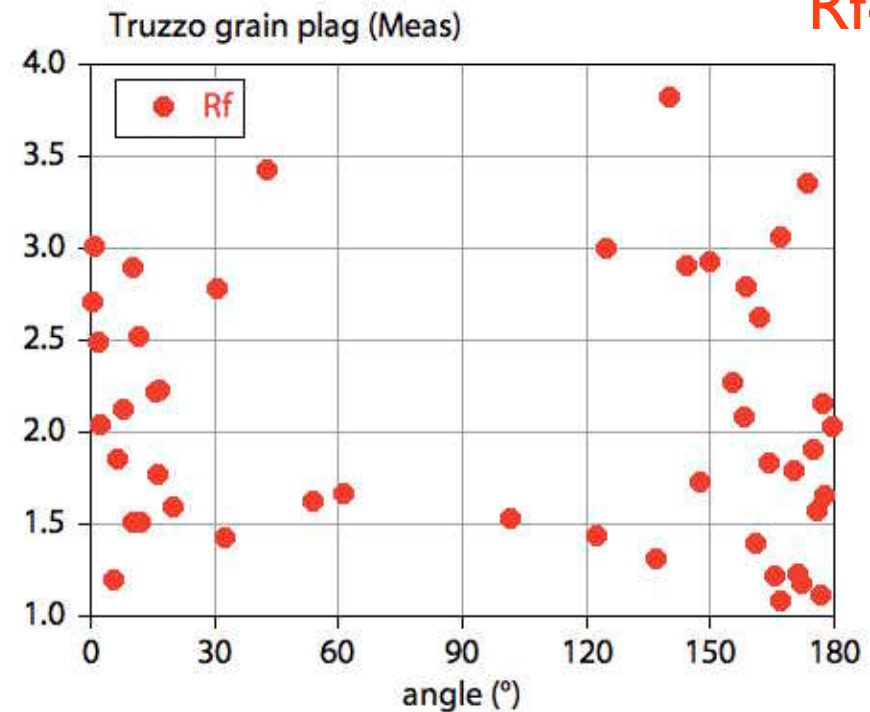
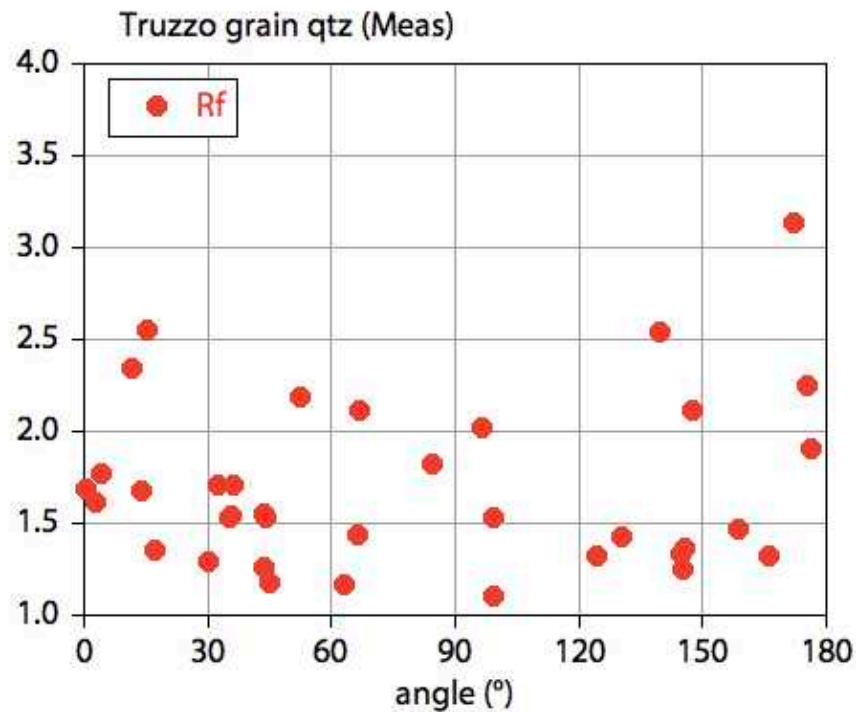


b/a( $r_{\text{equ}}$ )

# comparison: quartz - plagioclase



Rf- $\varphi$



# Übung 19 - Image analysis

Bildanalyse vom Typ 2 (Segmente) und Typ 3 (Fit-Ellipsen) durchführen

- Öffnen Sie eines der segmentierten Bilder im Ordner Meluzina (session 7)

Stellen Sie je eine Bitmap von Granat und Omphazit her.

- Führen Sie für beide Phasen die folgenden Analysen durch:

Bestimmen Sie das Histogramm der Korngrösse  $r_{\text{equ}}$ .

Bestimmen Sie das Achsenverhältnis (axial ratio)  $b/a$  aus einem Plot von  $b$  versus  $a$ .

Ist das Achsenverhältnis (aspect ratio)  $a/b$  abhängig von der Korngrösse? Beantworten Sie die Frage mit einem Plot von  $a/b$  als  $f(r_{\text{equ}})$ .

Konstruieren sie einen  $R_f$ - $\varphi$  - Plot.

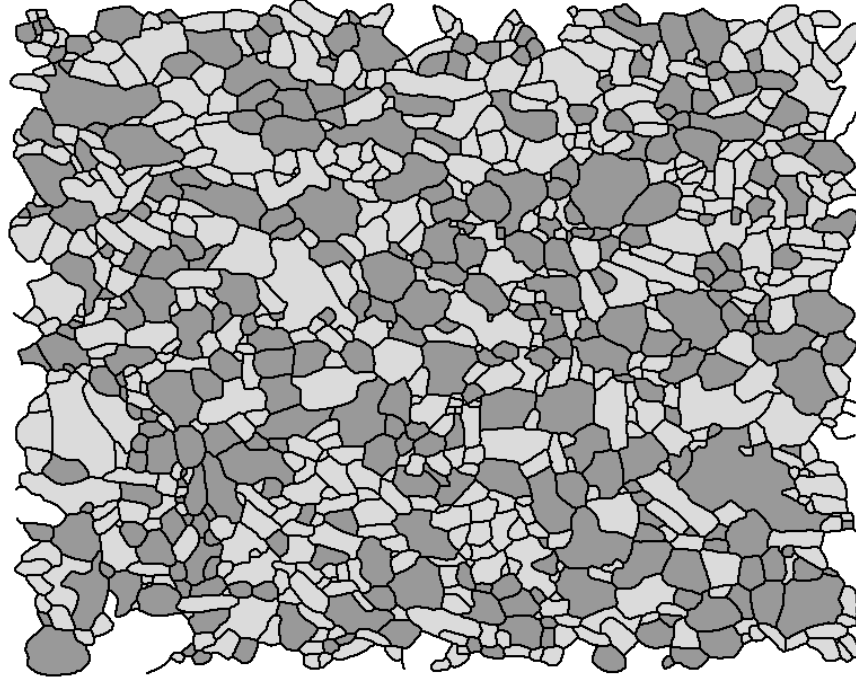
- Vergleichen Sie die Resultate,

- Interpretieren Sie.

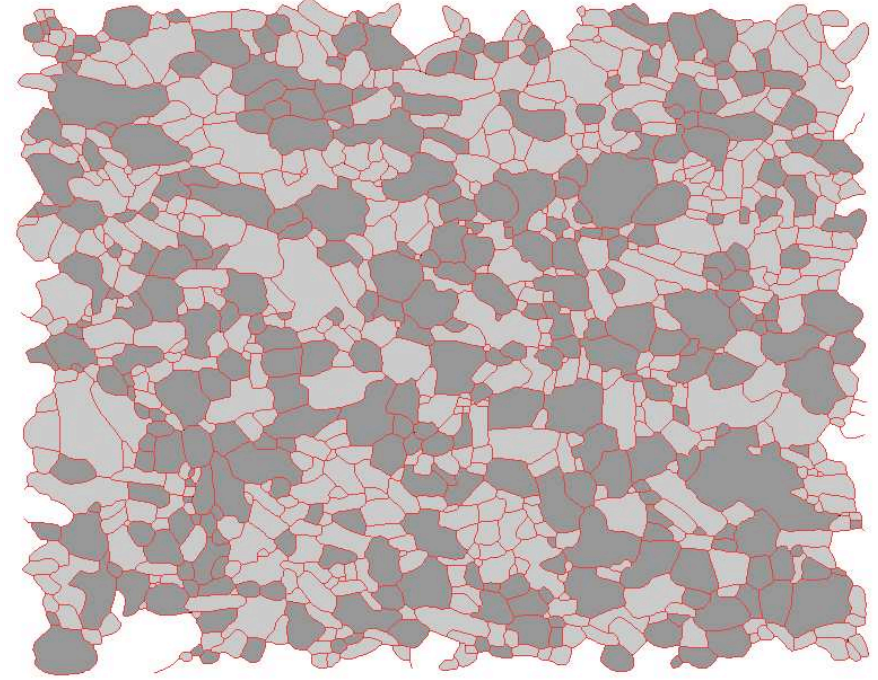
# grain size mapping



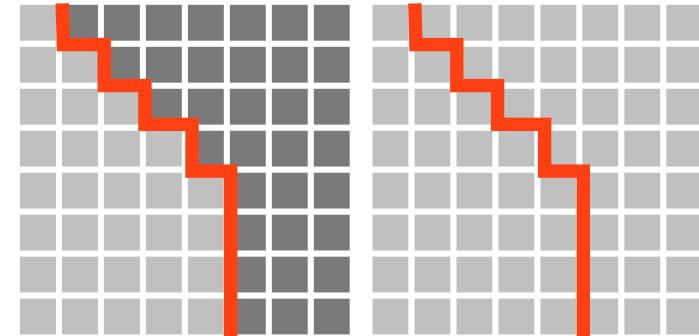
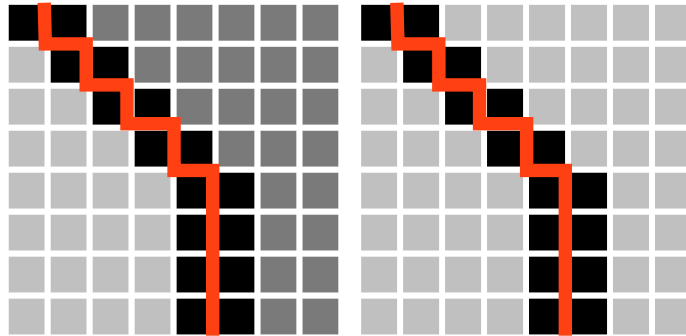
# restoring segments



100  $\mu\text{m}$



100  $\mu\text{m}$



in unscaled mode:  $\text{area}_{\text{corr}} = \text{area (px)} + \text{segment boundary (px)}$

# adding the boundary to the segment

use only if image is not scaled, i.e. area = pixel and length = pixel !!

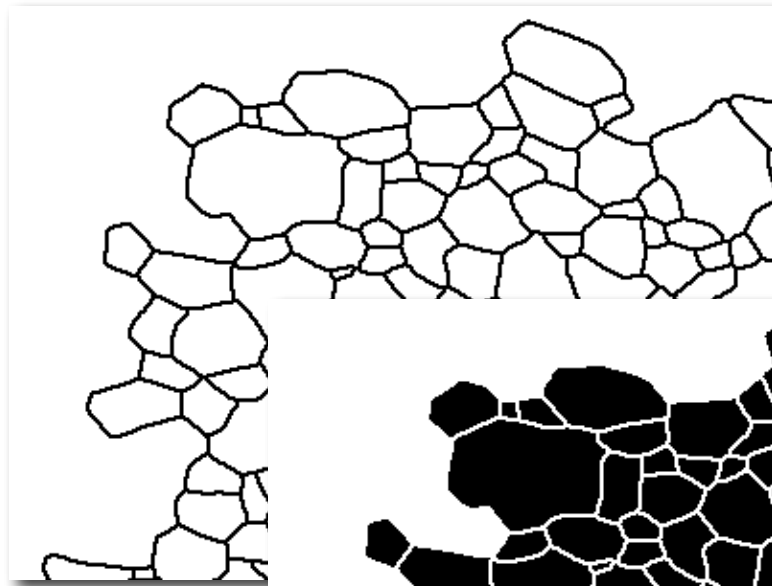
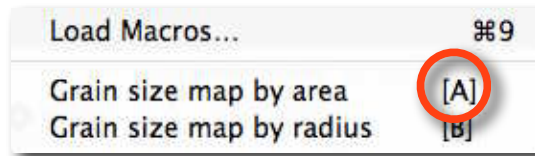
The screenshot shows a software window titled "Truzzo qtz (Meas)" with a toolbar and a data table. The table has columns: #, Area, X, Y, Len, r equ (C0), r equ corr (C1), Majr (C2), Minr (C3), and Angle (C4). The data rows are numbered 0 to 18. Two "Formula Entry" windows are overlaid on the table. The first window shows the formula  $c5 = \sqrt{c1/\pi}$  and the second window shows the formula  $c6 = \sqrt{(c1+c4)/\pi}$ . The status bar at the bottom left indicates "Row: 0 Column: 5".

#	Area	X	Y	Len	r equ (C0)	r equ corr (C1)	Majr (C2)	Minr (C3)	Angle (C4)
0									
1	1.0000	649.96	28.088	131.05	14.240	15.636	45.426	17.854	139
2	2.0000	67.628	35.225	164.17	20.944	22.156	51.792	33.876	44.3
3	3.0000	628.86	45.646	77.698	8.7404	10.056	30.981	9.8630	172
4	4.0000	562.64	63.167	137.40	16.803	18.058	43.888	25.733	32.3
5	5.0000	482.30	64.538	155.30	18.822	20.093	57.688	24.565	11.8
6	6.0000	228.23	146.05						
7	7.0000	510.50	207.66						
8	8.0000	567.36	180.53						
9	9.0000	374.41	176.21						
10	10.000	658.40	190.50						
11	11.000	410.00	205.92						
12	12.000	313.81	200.95						
13	13.000	342.15	247.04						
14	14.000	153.96	232.39						
15	15.000	239.10	263.20						
16	16.000	441.18	276.12						
17	17.000	555.40	269.66						
18									

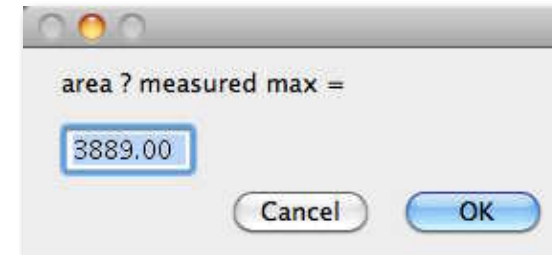
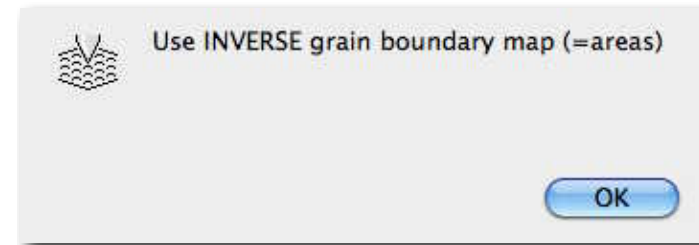
$$c5 = \sqrt{c1/\pi}$$

$$c6 = \sqrt{(c1+c4)/\pi}$$

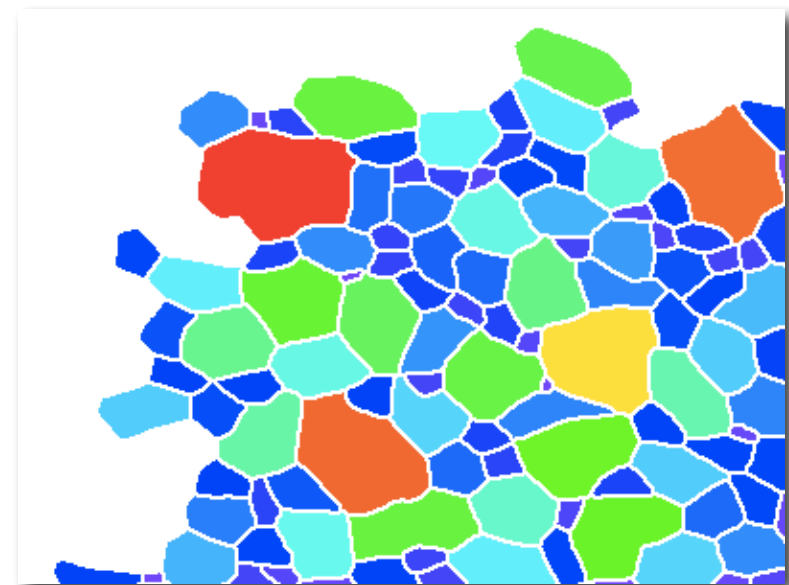
# Lazy grain size map



no particles  
touching edge

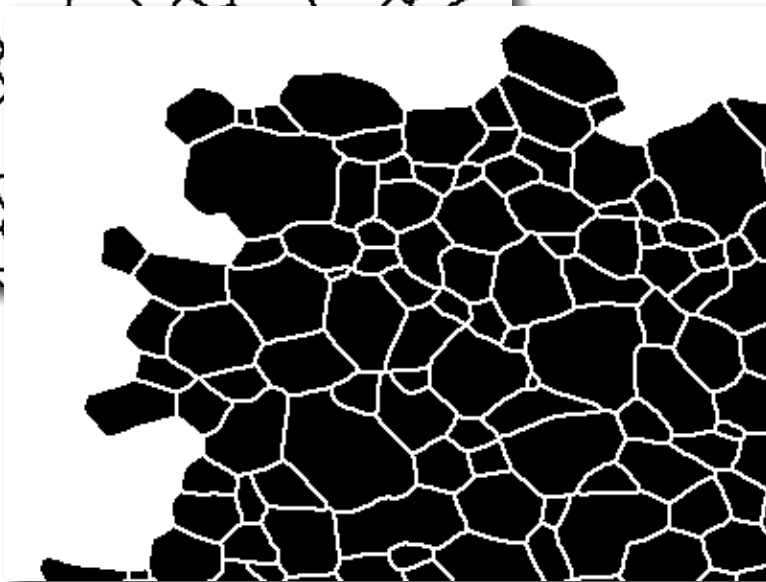
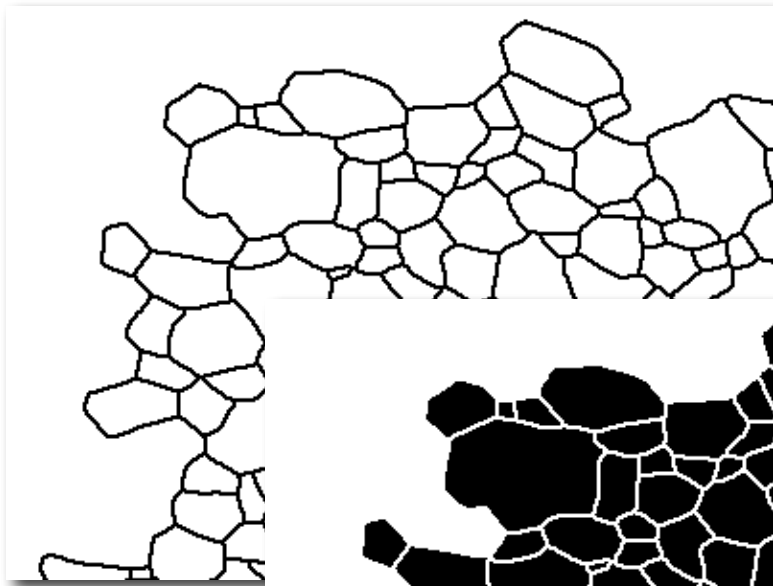
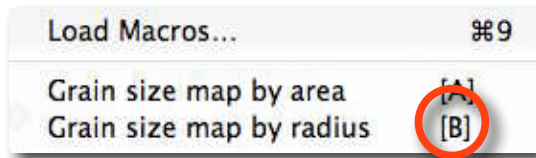


select max=3000

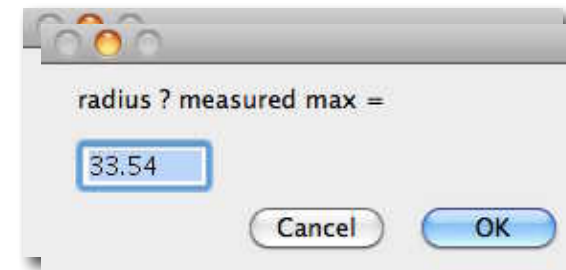
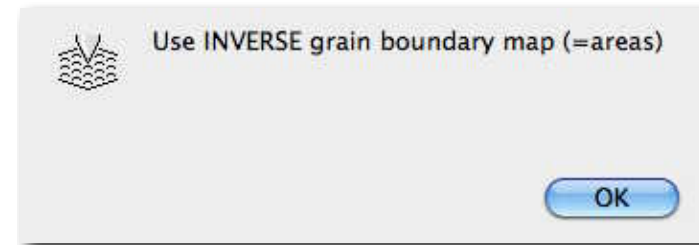


area > 3000 is red

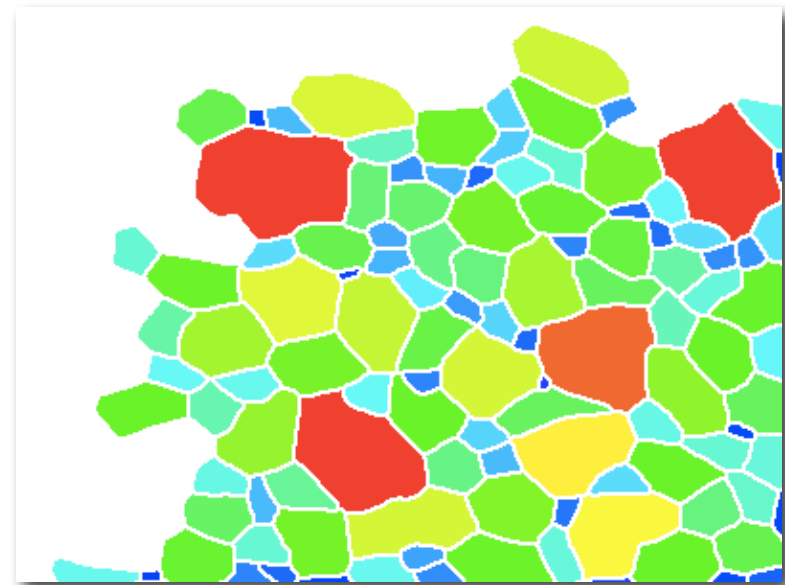
# Lazy grain size map



no particles  
touching edge

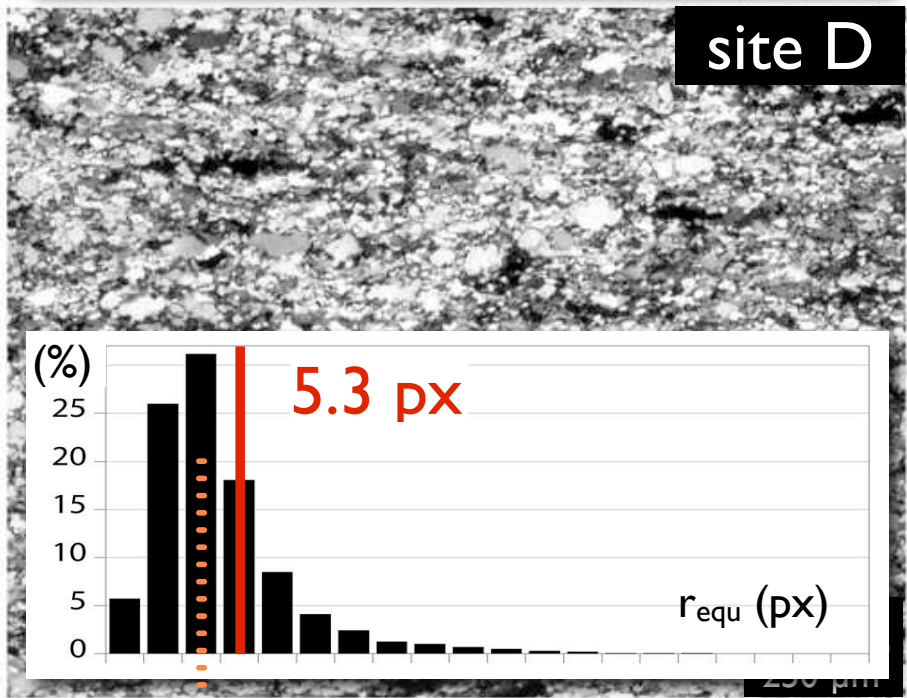
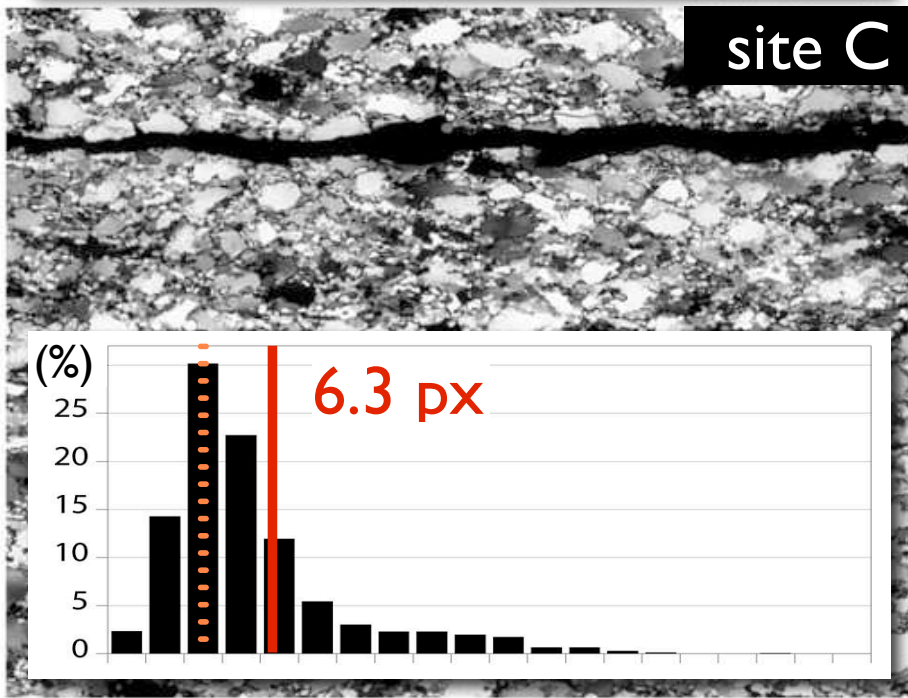
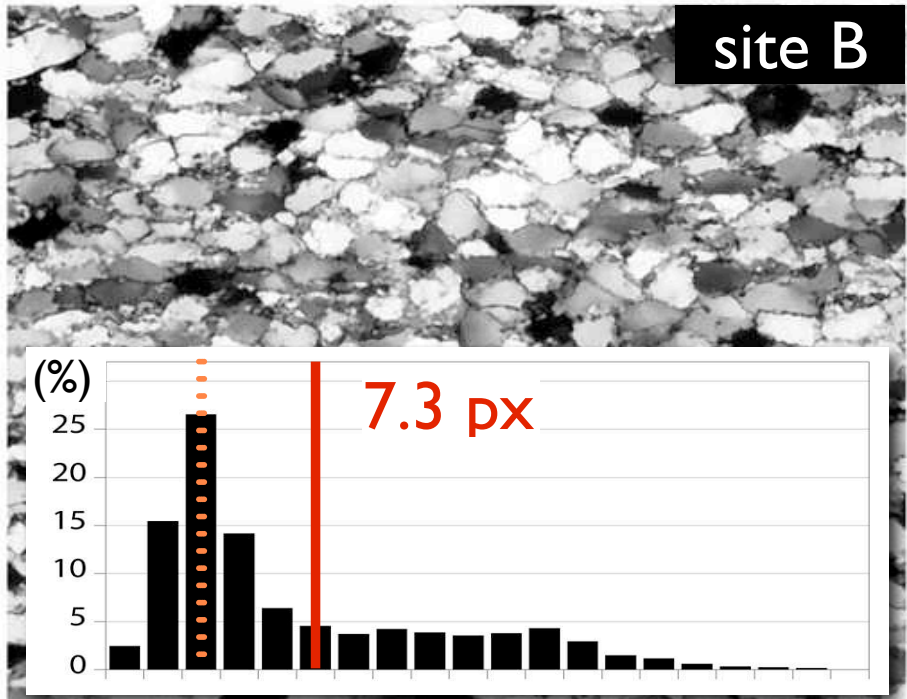
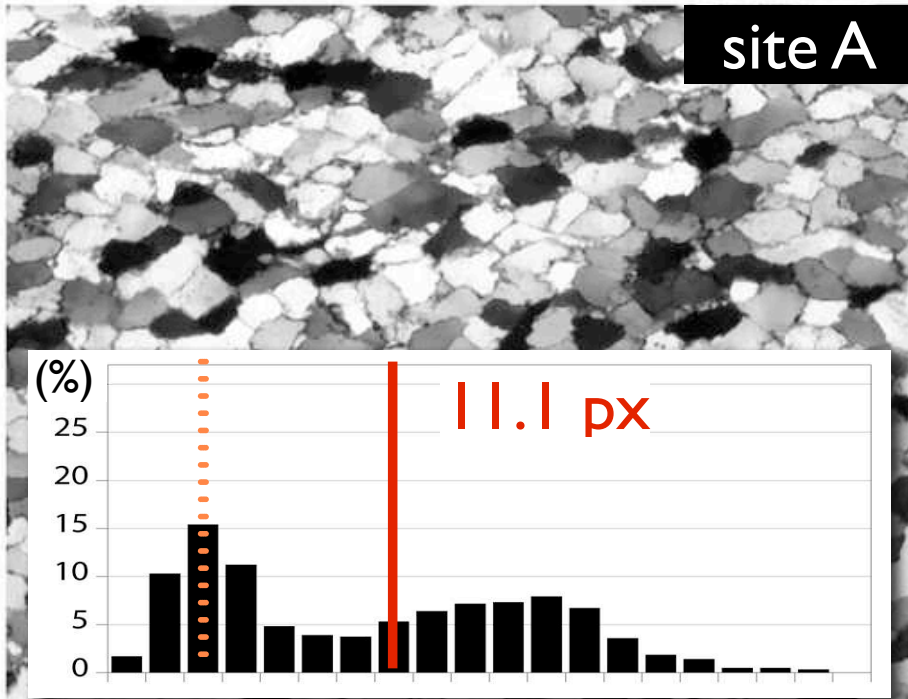


select max=30



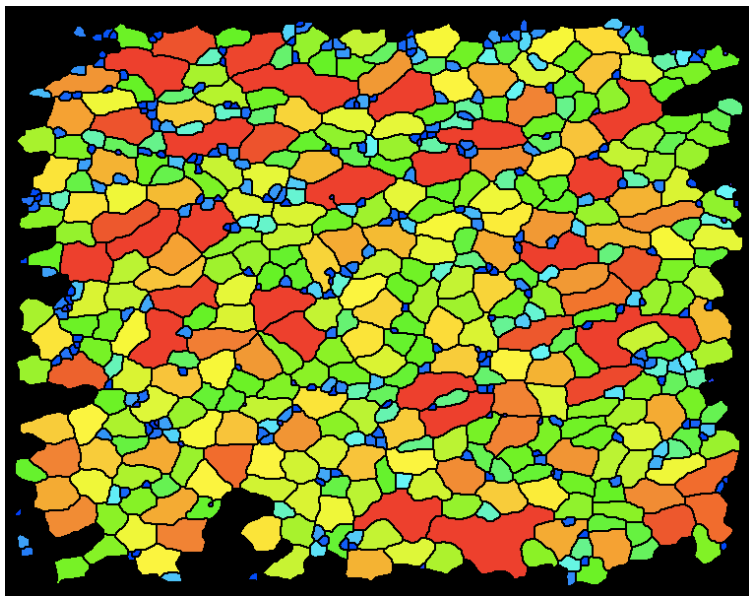
radius > 30 is red



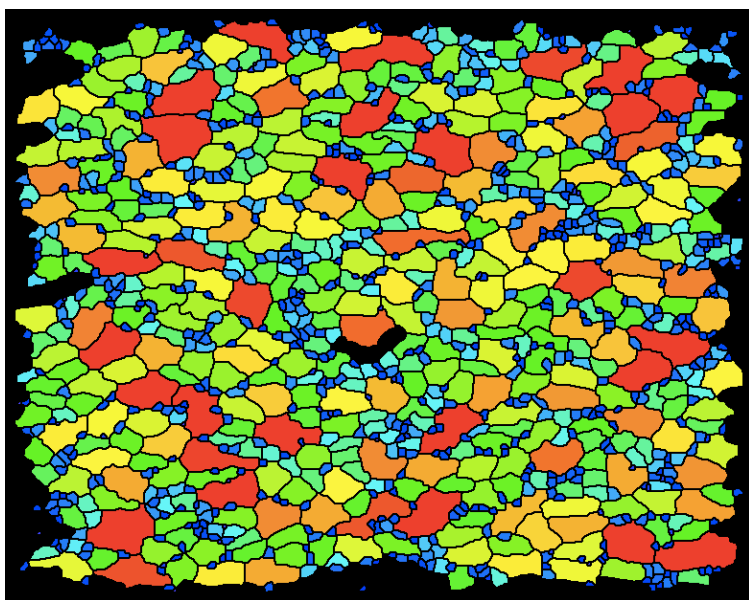




# linear size mapping (diameter)

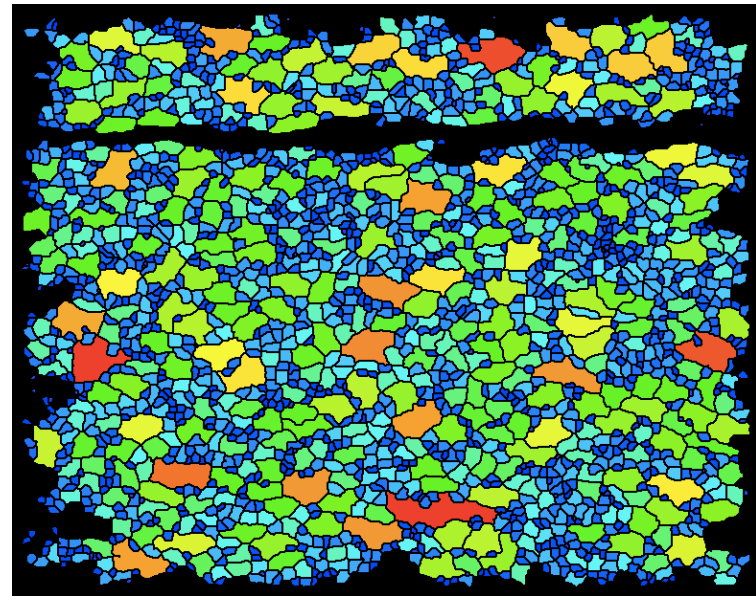


A

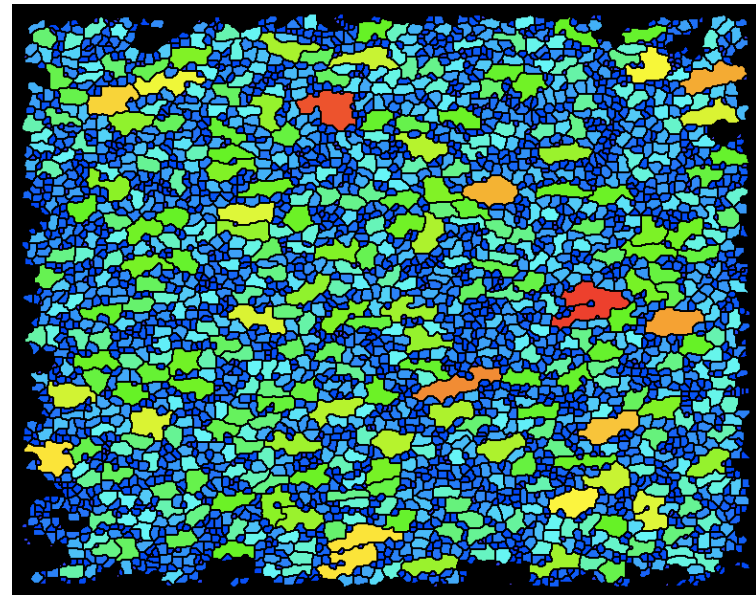


B

scaled by equivalent diameter



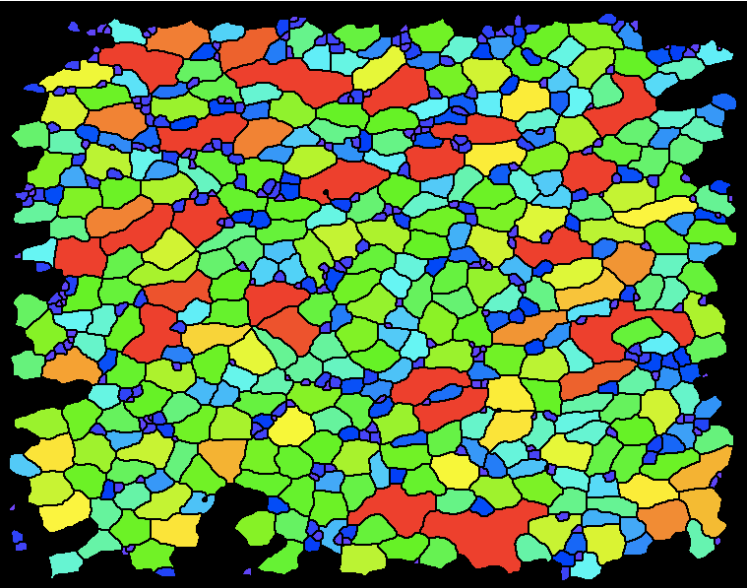
C



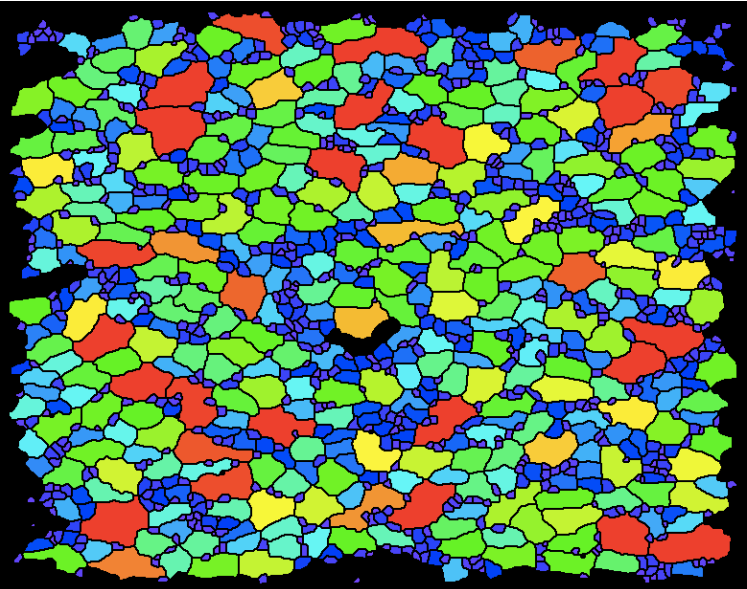
D



# area size mapping

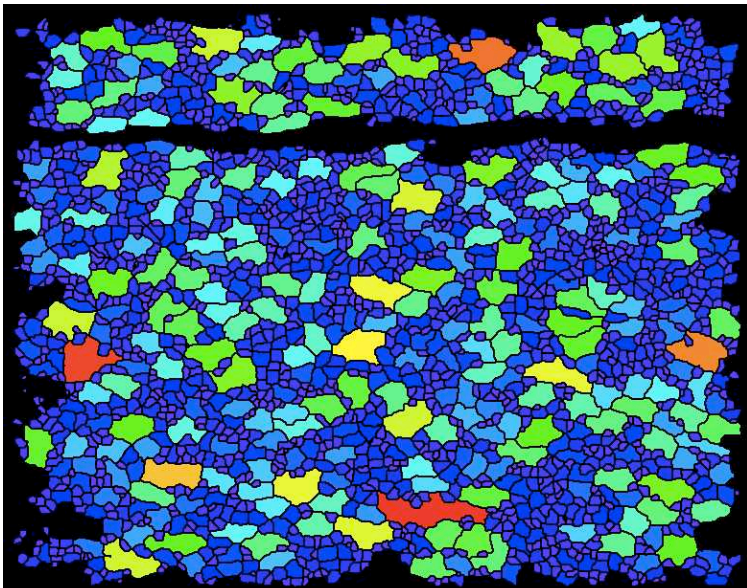


A

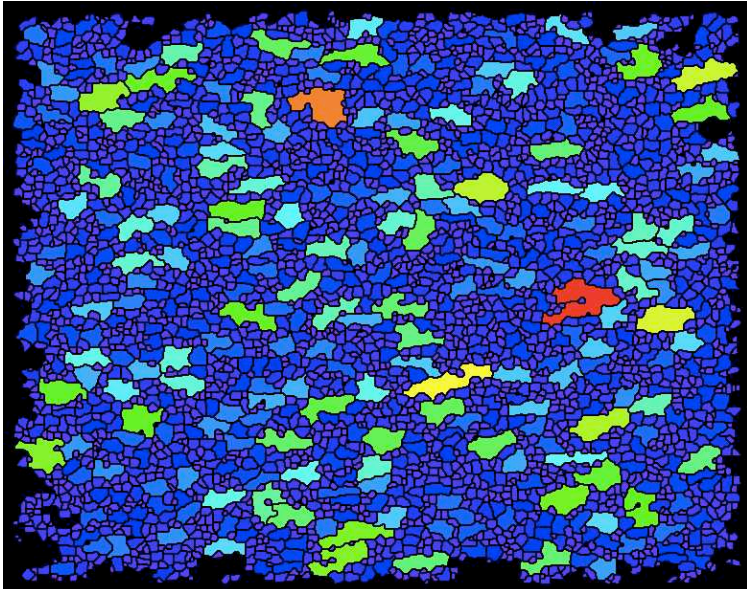


B

scaled by area



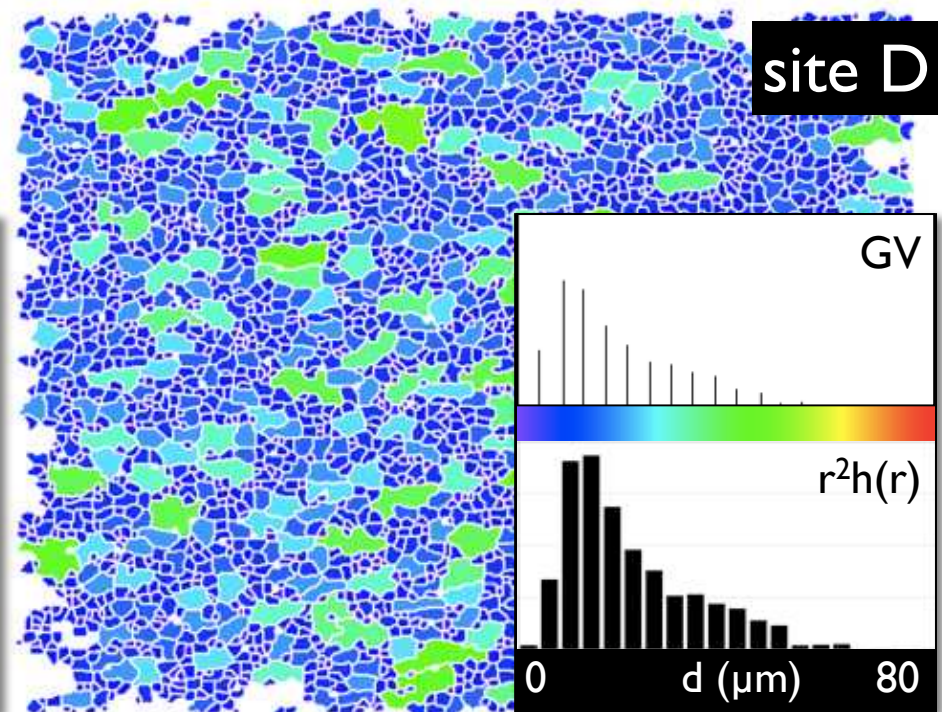
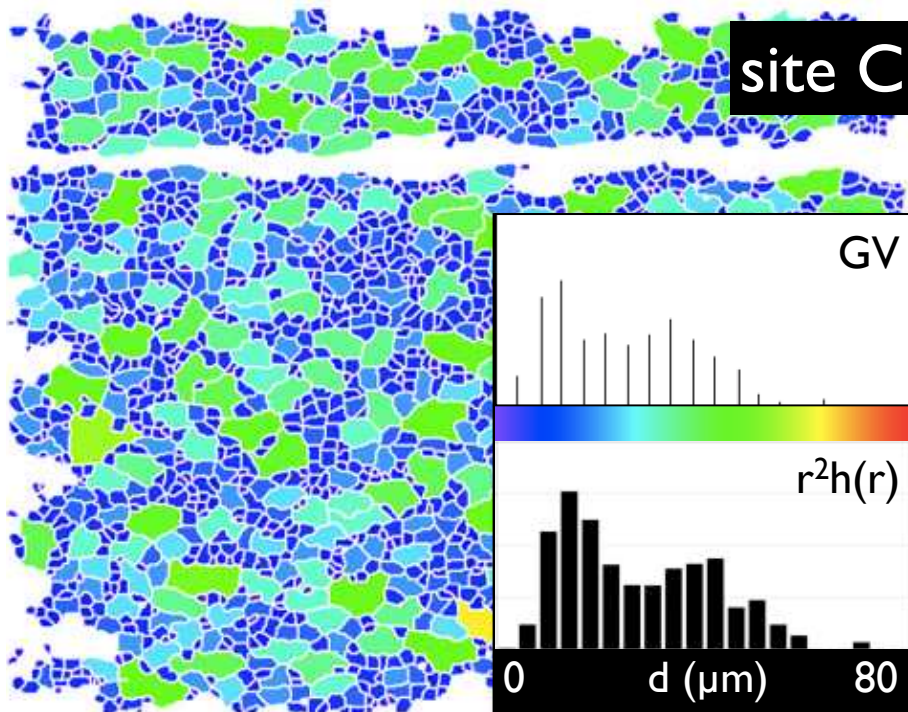
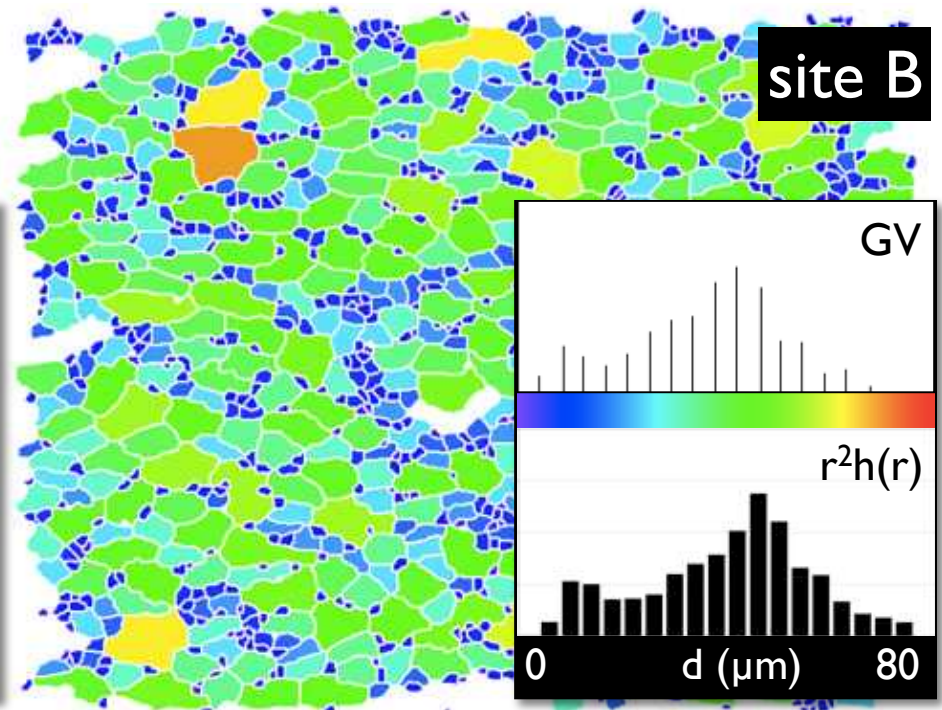
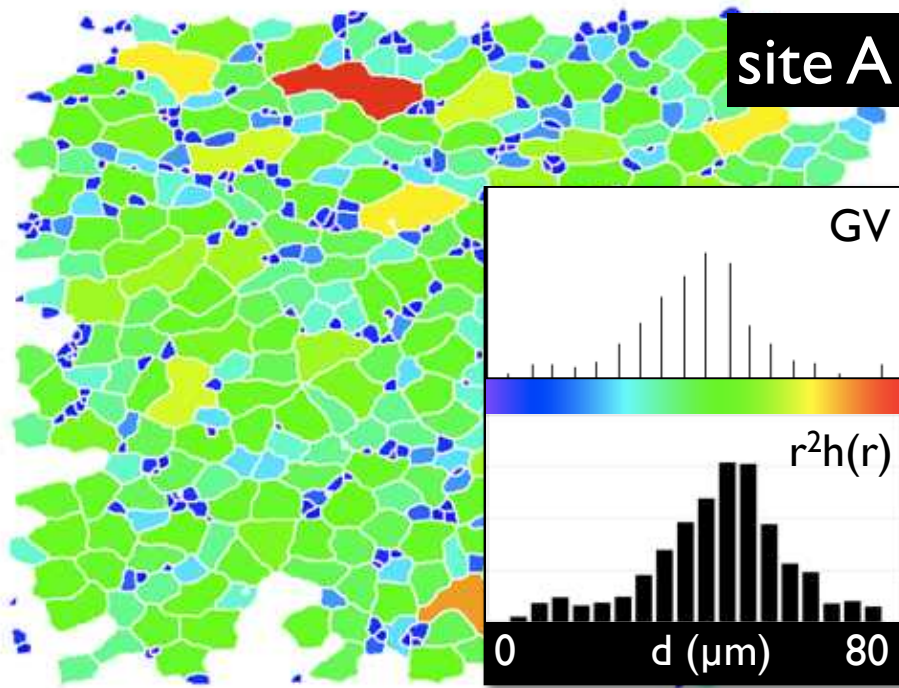
C



D

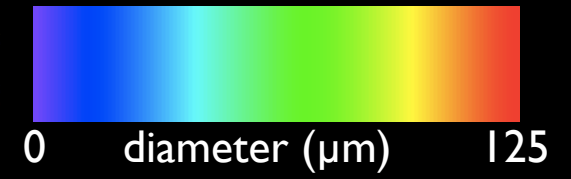
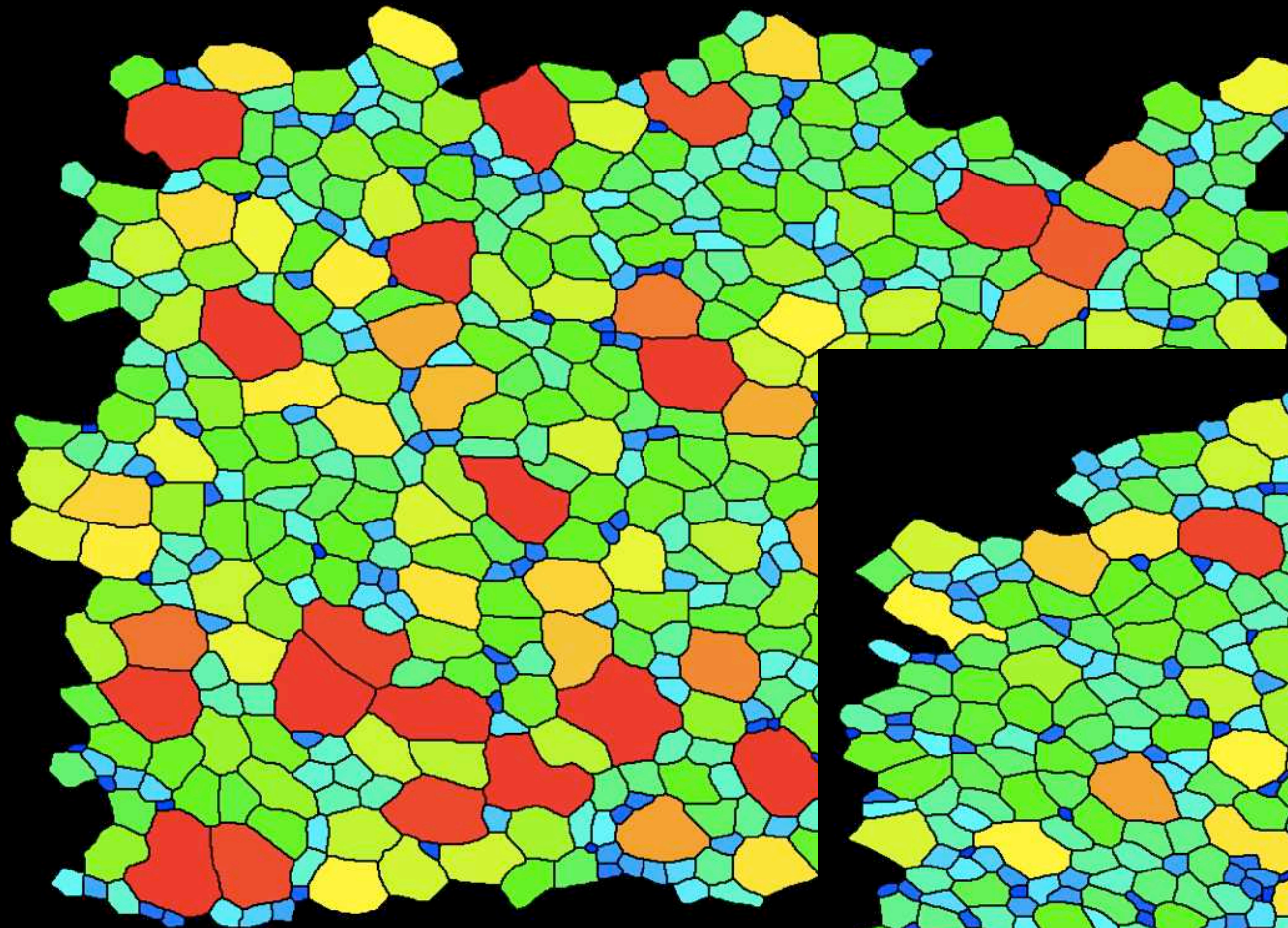




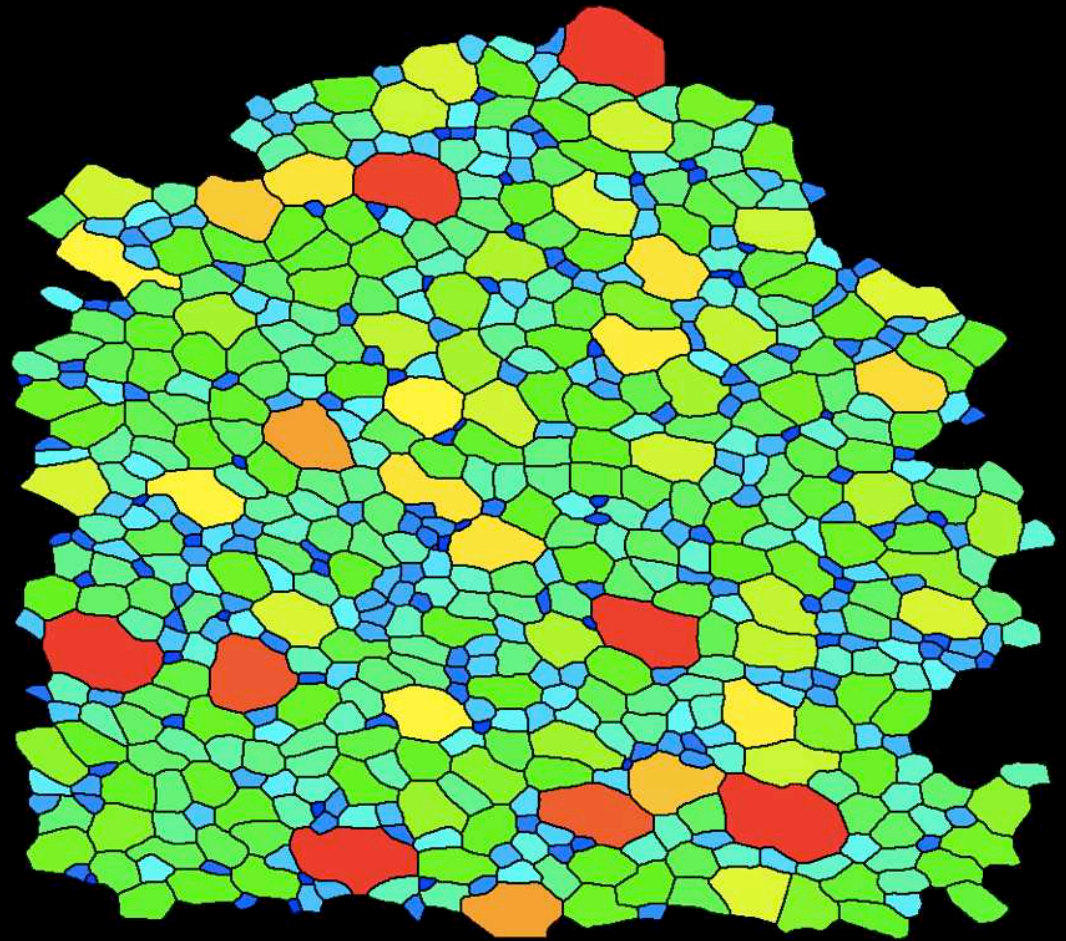




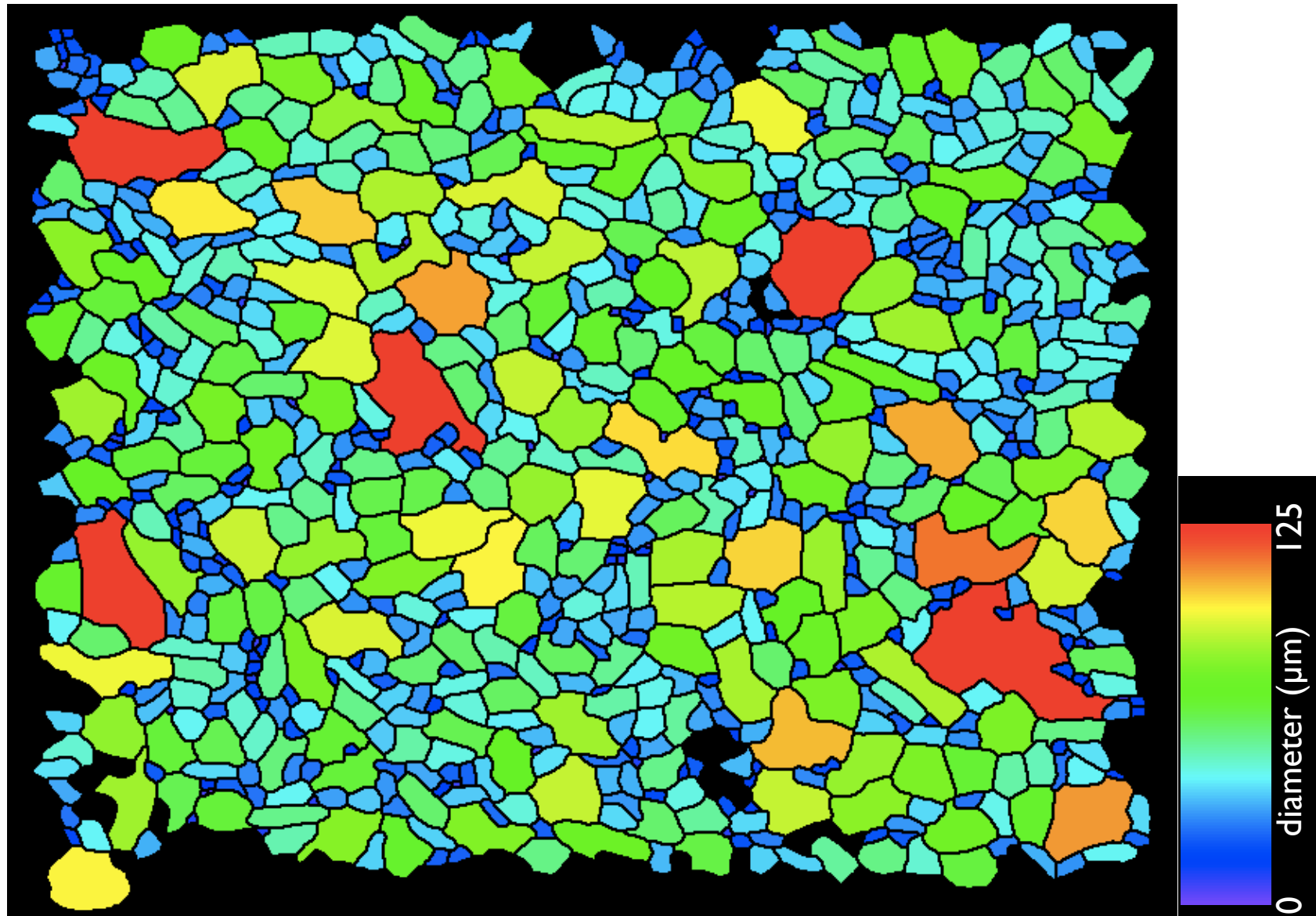
Carrara marble 39white



Carrara marble 38grey

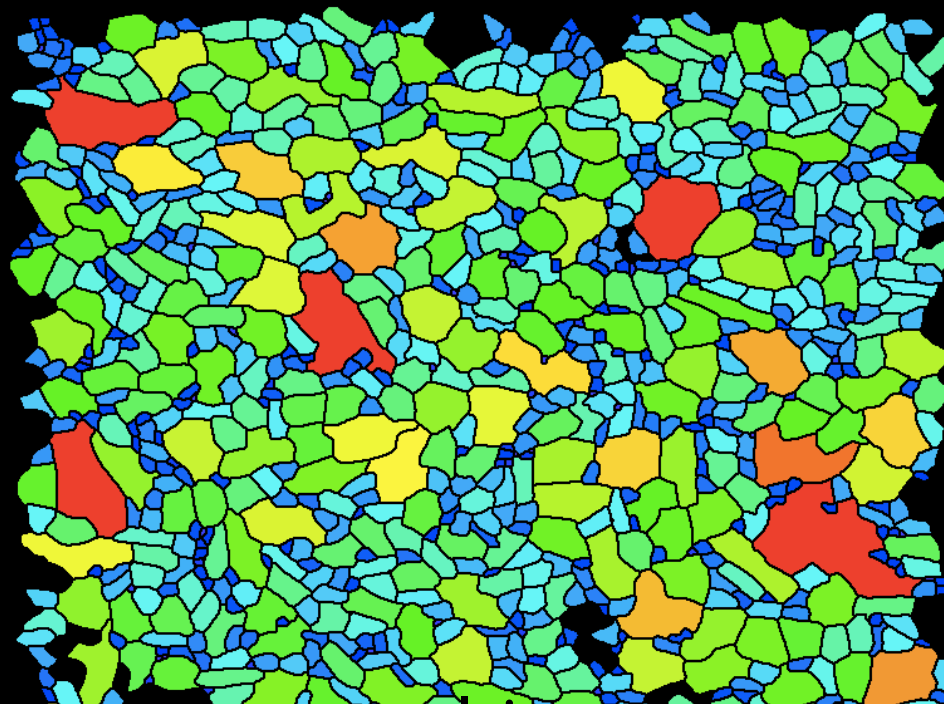


# calcite - anhydrite aggregate (HIP)



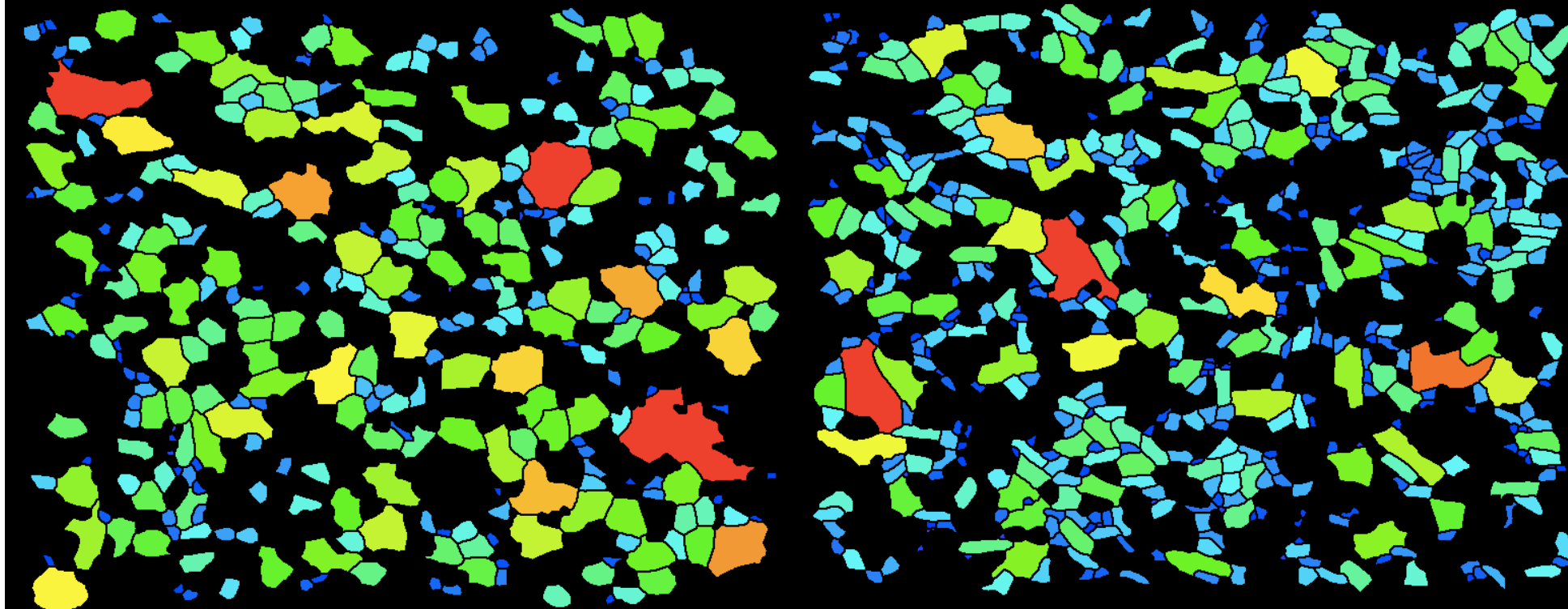


50:50  
cc:anh



calcite

anhydrite

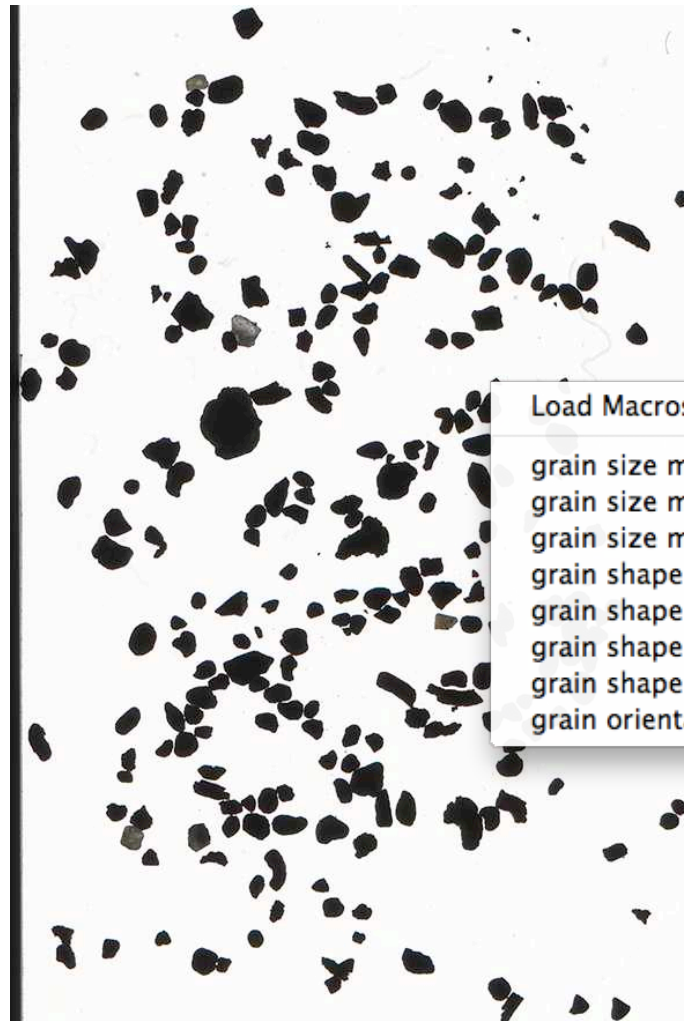


# property maps

# Eigenschaften visualisieren



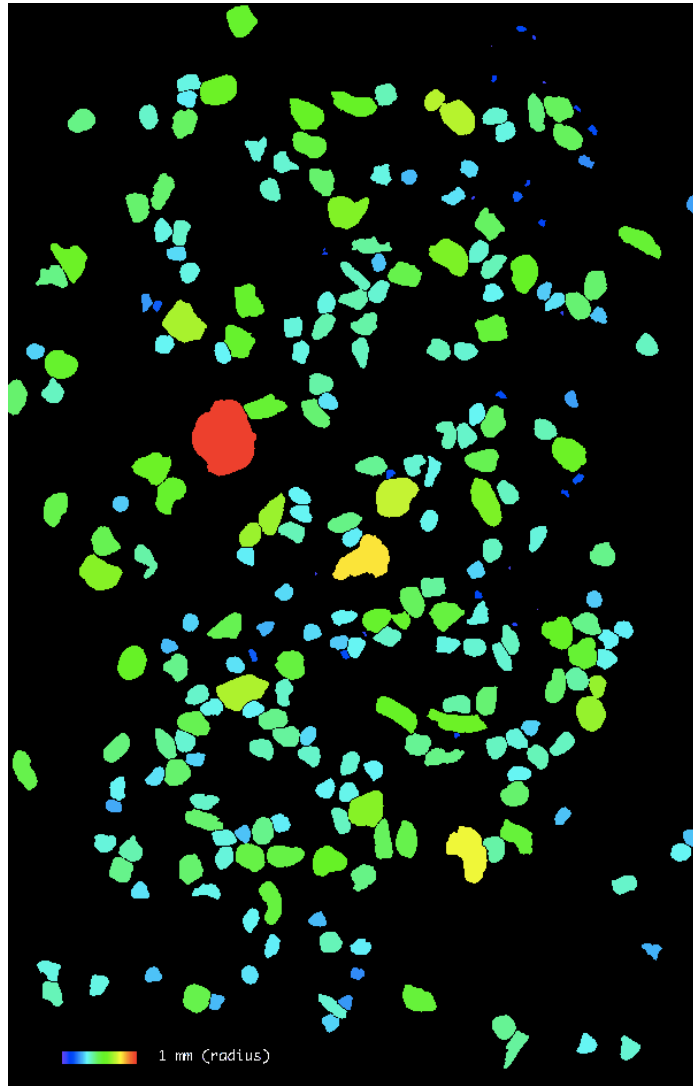
Auflicht



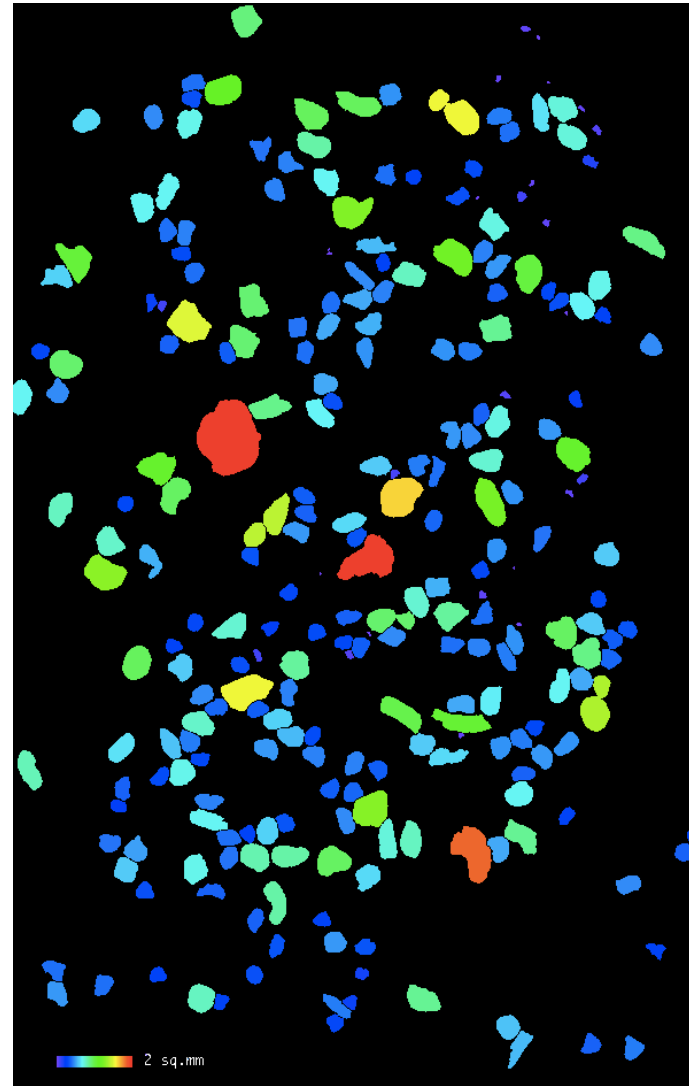
Load Macros...	#9
grain size map by pixel area	[A]
grain size map by pixel radius	[B]
grain size map by long diameter	[C]
grain shape map - axial ratio	[D]
grain shape map - aspect ratio	[E]
grain shape map - shape factor 1	[F]
grain shape map - shape factor 2	[G]
grain orientation map	[H]

Durchlicht

# Lazy grain mapping - size

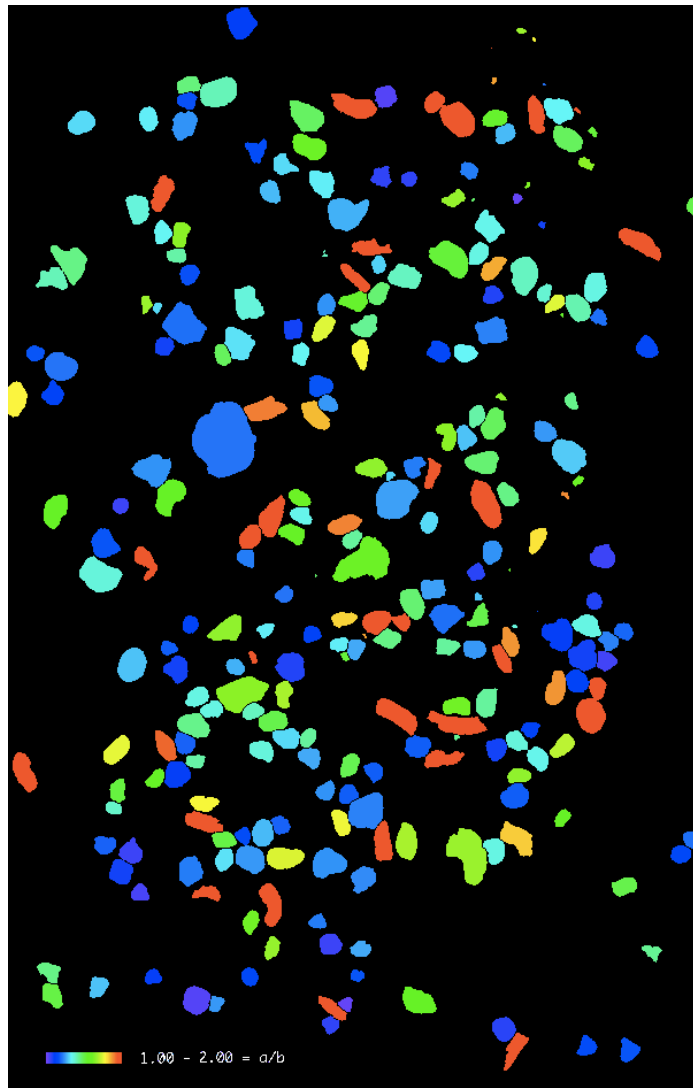


radius

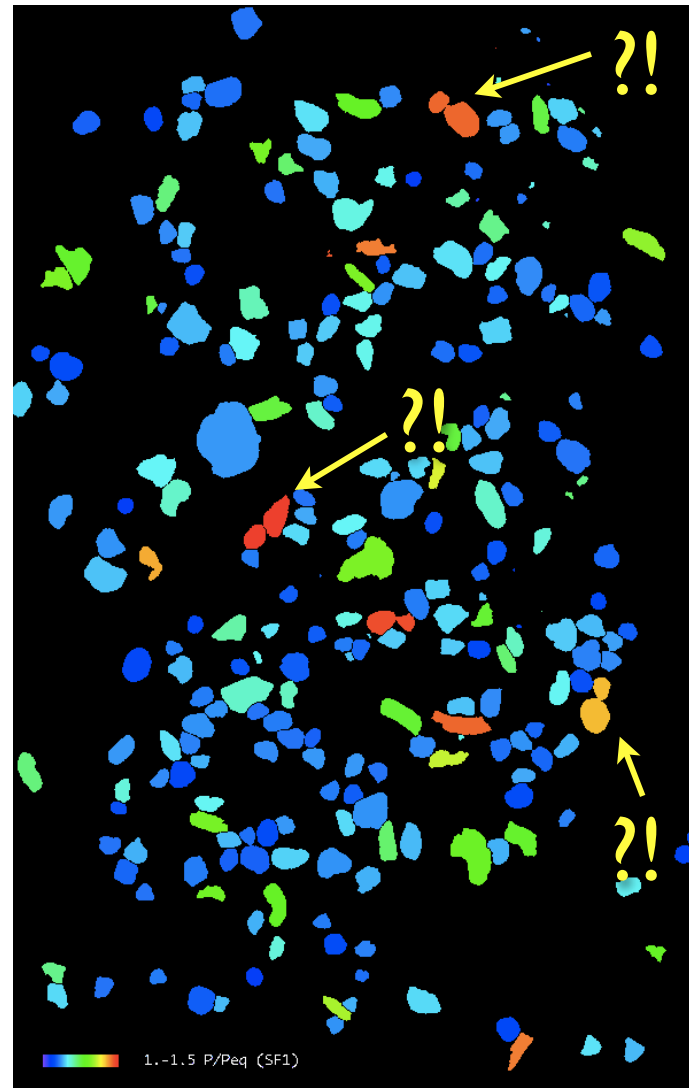


area

# Lazy grain mapping - shape



aspect ratio a / b



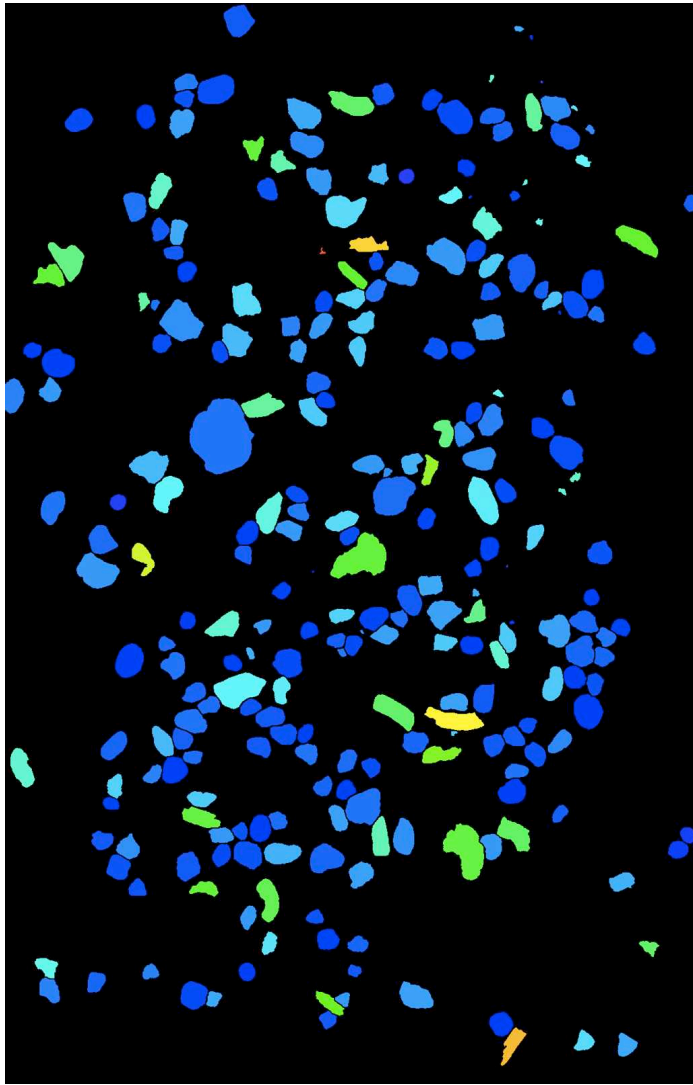
rot = SF<sub>1</sub> hoch  
= weniger rund

blau = SF<sub>1</sub> tief  
= rund

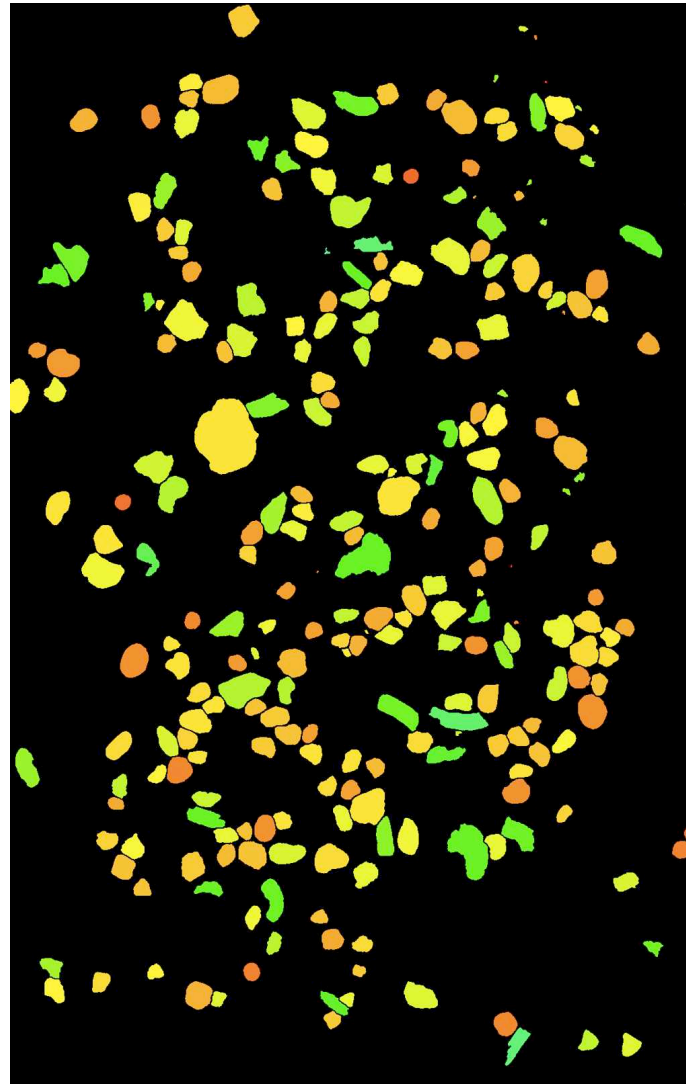
SF<sub>1</sub> = P / P<sub>equ</sub>



# after correction



$$SF_1 = P / P_{\text{equ}} (> 1.0)$$



$$SF_2 = A / A_{\text{equ}} (< 1.0)$$

rot = SF<sub>2</sub> hoch  
= rund

blau = SF<sub>2</sub> tief  
= weniger rund

# Übung 20 - Lazy grain mapping

Geometrische Eigenschaften visualisieren

- Öffnen Sie TOS02Tbitsepscal.tif im Ordner "TOSsedi" (session 7)

Laden Sie das macro "Lazy grain mapping". Stellen Sie alle verfügbaren Eigenschaften als property map dar.

Interpretieren Sie das Histogramm der einzelnen maps. Eventuell die cut-off Werte ändern.

- Stellen Sie je eine Bitmap der grösseren und der kleineren Korngrößen - Fraktion her. Stellen Sie fest, ob die Form Korngrößen abhängig ist.



# DBA 2014


# session 8

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
→ URZ - Universitätsrechenzentrum  
→ VIA - Vorlesungsverzeichnis  
→ RESEARCH - Personenseite

HOME Contact Studium Geowissenschaften Lehrveranstaltungen Vorträge und Links Strukturgeologie  
Rock Deformation Projects & Software Workshops Textbook DDM Macros Image Macros Image Analysis

LEHRVERANSTALTUNGEN



...ceci n'est pas "L'appel des cimes" de René Plagwitz...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehölle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageDM bzw. image kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen.  
Kennenlernen der ImageDM software (Mac/CSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Exportation (2-D -> 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software Image DM, bzw. image (alle public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungszahlung möglich)
- Harterter, P. (1993). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET** [earth.unibas.ch](http://earth.unibas.ch)  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

TROMSDO GEOMAGING

→ TROMSDO CRUSTAL DYNAMICS HOMEPAGE (English)  
→ TROMSDO GEOLOGY HOMEPAGE (Norwegian)  
→ TROMSDO UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>

# Semesterfahrplan: Fahrplanänderung

			Freitag CR 14-17	Montag CR 14-17
	Thema	Doz.	Gruppe A	Gruppe B
1	Images for image analysis - intro: ImageSXM	RH	19-Sep-2014	22-Sep-2014
2	Digital Images - Pixels - LUTs	RH	26-Sep-2014	29-Sep-2014
3	Explore / pre-process digital images - intro: imageJ	RK	3-Oct-2014	6-Oct-2014
4	POP segmentation - post-processing	RK	10-Oct-2014	13-Oct-2014
5	Mathem./Punkt-Operationen Verschneide-Operationen	RH	17-Oct-2014	
		RH		27-Oct-2014
	(fällt aus)			
			nur Freitag CR 14-17	
6	Filtern - Kantendetektion - NOP segmentation	RH	7-Nov-2014	
7	Analyze: segments - best-fit ellipses - property maps	RH	14-Nov-2014	
8	(Fourier-Transformationen) Autokorrelation	RH	21-Nov-2014	
	(Dies Academicus)			
9	Korngrößen-Analyse Stereologie - Kontaktflächen	RH	5-Dec-2014	
Test			12-Dec-2014	

pro Nachmittag: 1. Teil: Vorlesung (Einführung in das Thema) - 2. Teil: Übungen  
Besprechung der Übungen am Anfang der nächsten Vorlesung

# Übung 19 - Image analysis

Bildanalyse vom Typ 2 (Segmente) und Typ 3 (Fit-Ellipsen) durchführen

- Öffnen Sie eines der segmentierten Bilder im Ordner Meluzina (session 7)

Stellen Sie je eine Bitmap von Granat und Omphazit her.

- Führen Sie für beide Phasen die folgenden Analysen durch:

Bestimmen Sie das Histogramm der Korngrösse  $r_{\text{equ}}$ .

Bestimmen Sie das Achsenverhältnis (axial ratio)  $b/a$  aus einem Plot von  $b$  versus  $a$ .

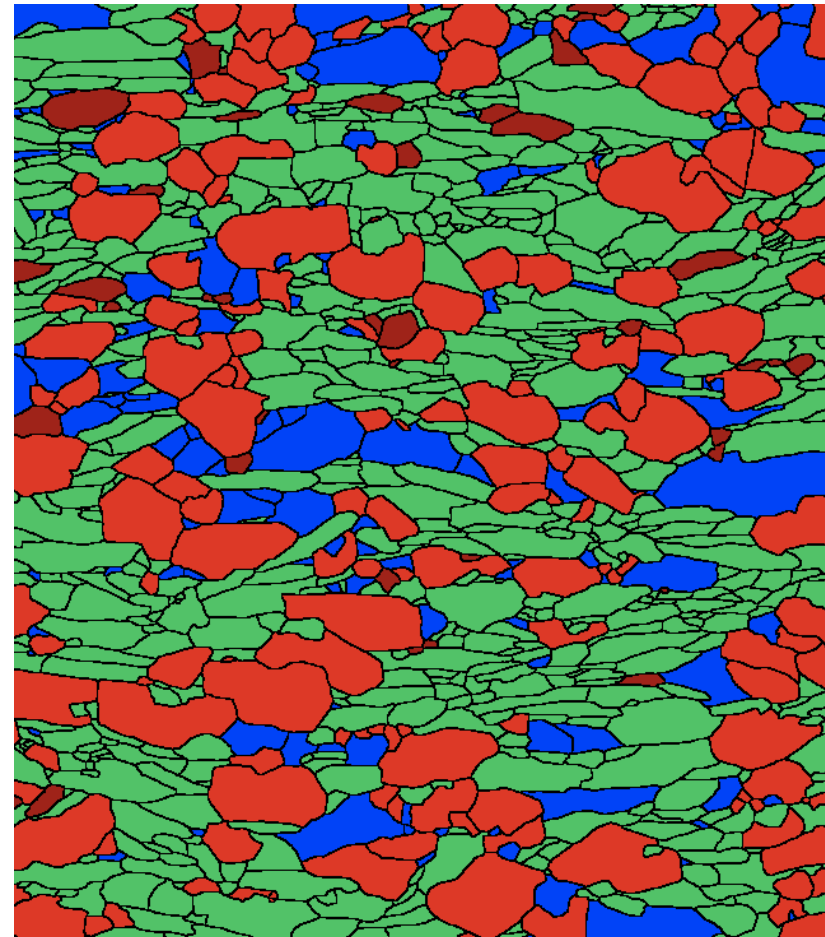
Ist das Achsenverhältnis (aspect ratio)  $a/b$  abhängig von der Korngrösse ?

Beantworten Sie die Frage mit einem Plot von  $a/b$  als  $f(r_{\text{equ}})$ .

Konstruieren sie einen  $R_f$ - $\varphi$  - Plot.

- Vergleichen Sie die Resultate,

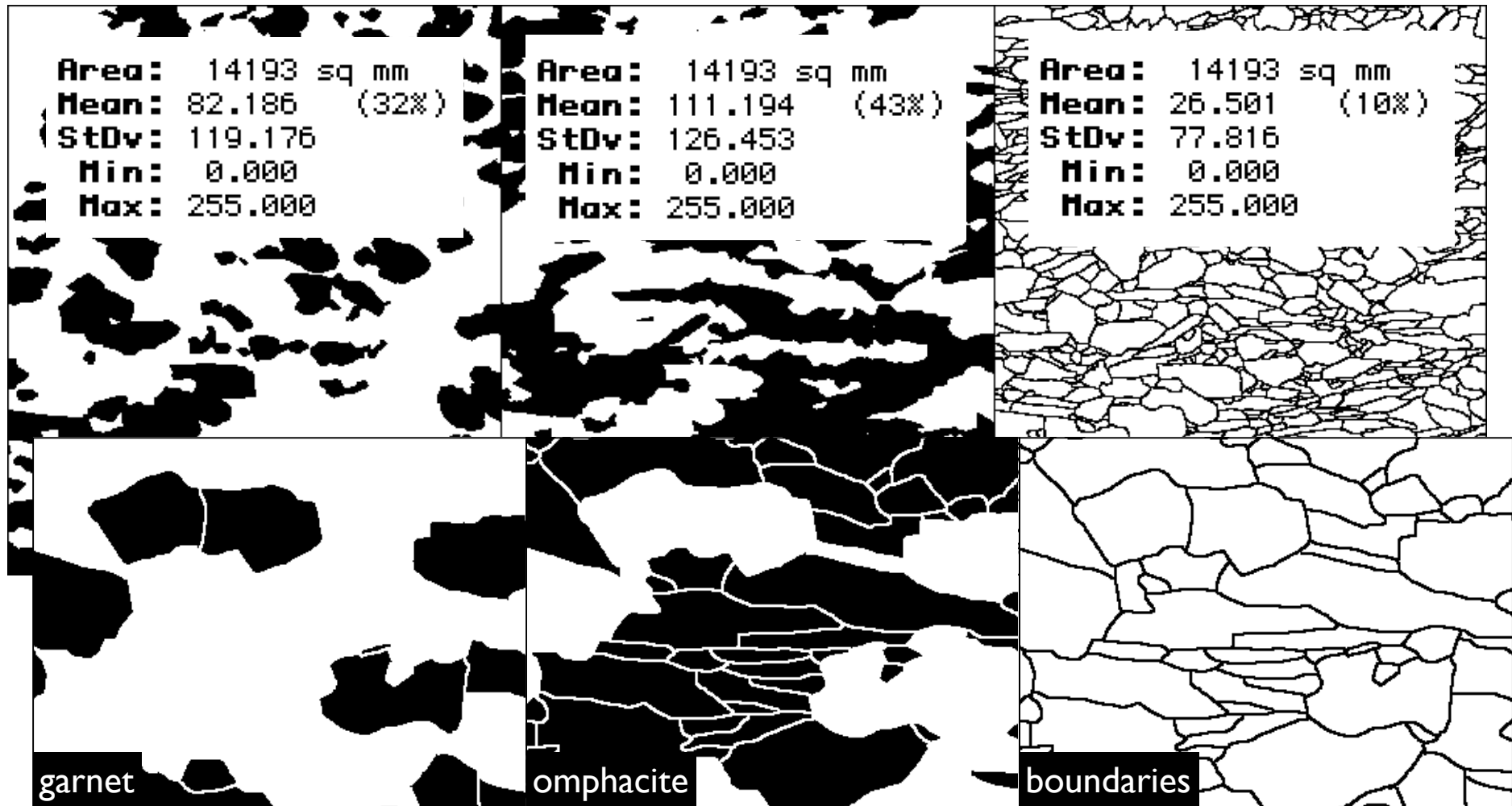
- Interpretieren Sie.



Masstab  
11.49604px / mm



# Auswertung der bitmaps



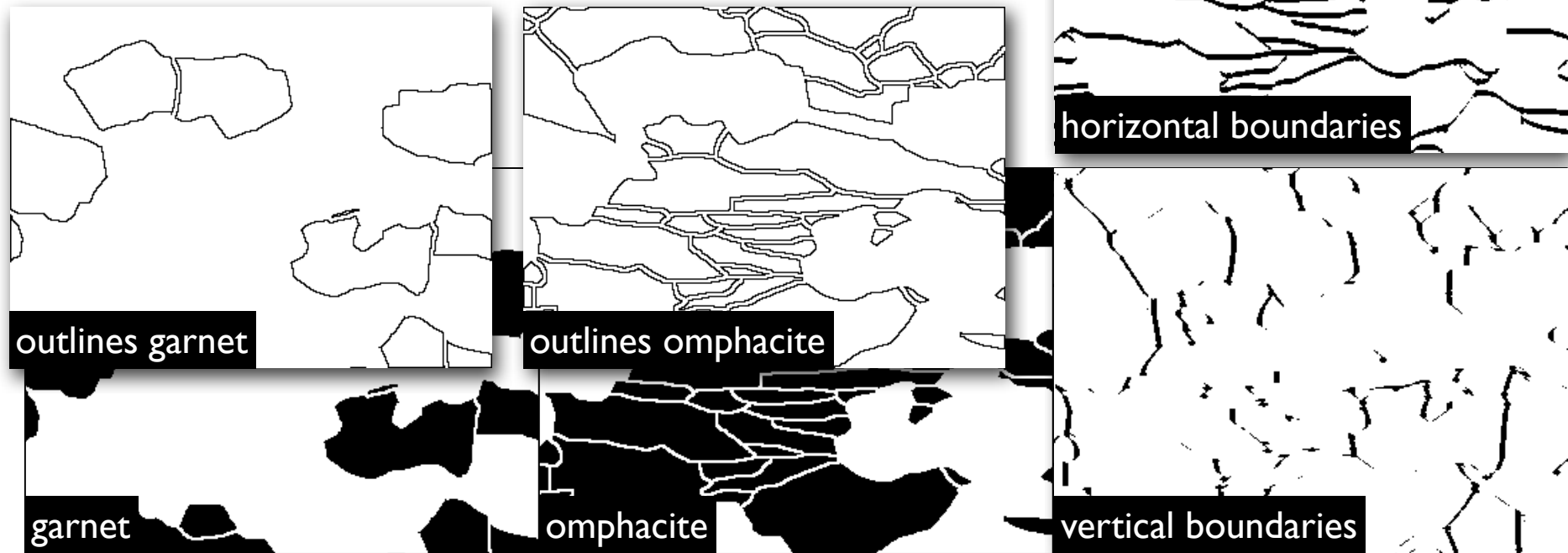
garnet  
 grain area = 32% of image (1276 · 1470 px)  
 phase are = 35% (= incl. ~3% outlines)

omphacite  
 grain area = 43% of image (1276 · 1470 px)  
 phase area = 50% (= incl. ~7% outlines)

ratio  $vol_{\text{garnet}} : vol_{\text{omphacite}} = 59 : 41$

# Auswertung der bitmaps

horizontal: copy paste move up 2px DoOr  
copy paste move right 4px DoAnd  
vertical: copy paste move right 2px DoOr  
copy paste move up 4px DoAnd



garnet  
6.379 outline (average GV)

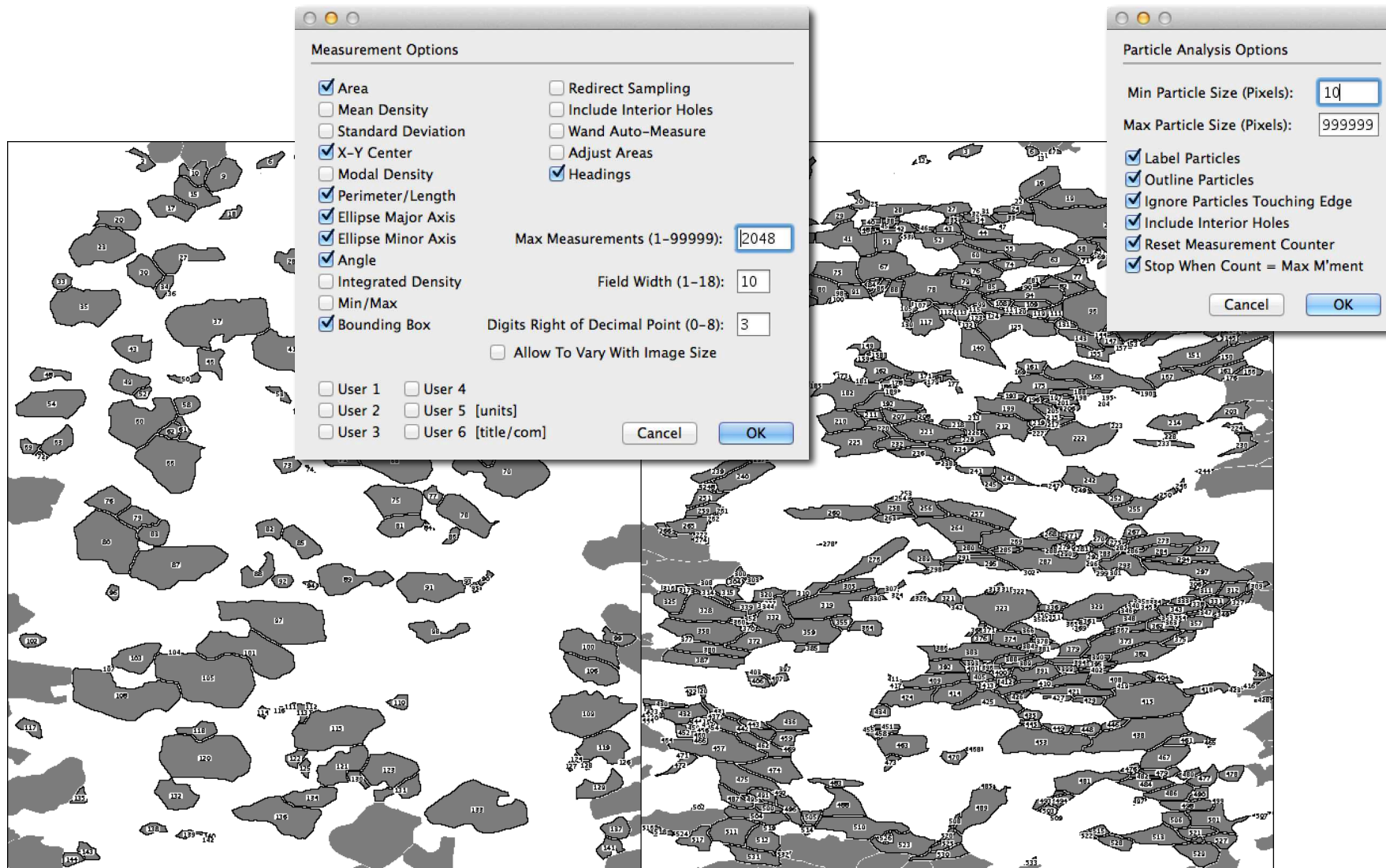
omphacite  
outline = 15.554 (average GV)

grain boundaries  
horizontal = 28.37 (average GV)  
vertical = 10.20 (average GV)

ratio  $outline_{\text{garnet}} : outline_{\text{omphacite}} = 29 : 71$

ratio  $gb_{\text{horizontal}} : gb_{\text{vertical}} = 74 : 26$

# Analyze Particles



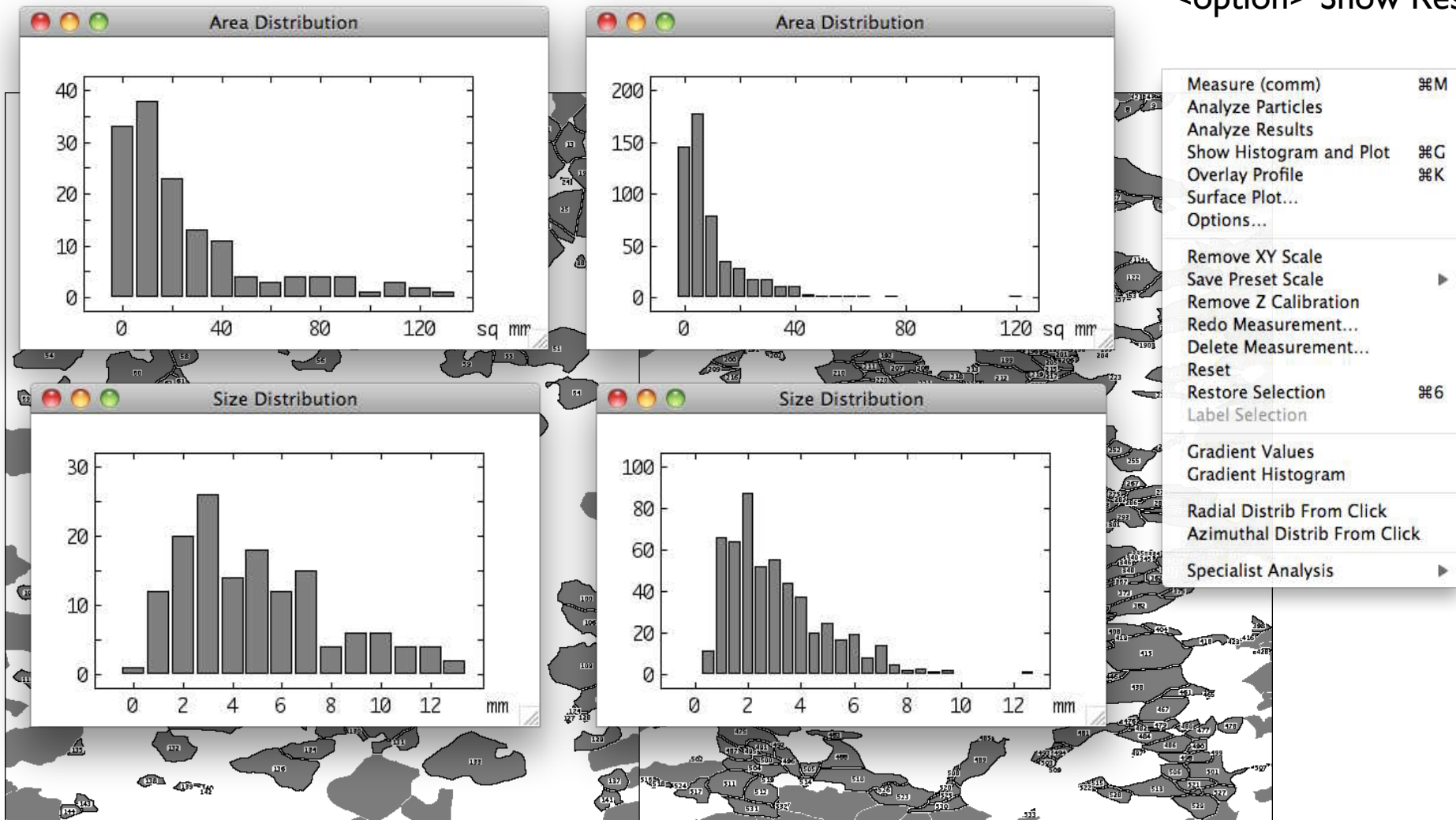
garnet  
number of grains = 144

omphacite  
number of grains = 533

# Analyze Results

wie mach ich's ?

<option> Show Results



Font size 14

Plot size 250 · 150

# Kaleidagraph: first results

average values	garnet	omphacite
number of grains	144	533
$d_{\text{equ}}$ (mm)	4.94	1.53
long diameter (mm)	6.90	5.54
short diameter (mm)	3.61	1.78
b / a	0.56	0.37
b / a BoundingBox	0.73	0.49
a / b	1.98	3.33
SFI = $P / P_{\text{equ}}$	1.28	2.95
a / b BoundingBox	1.54	2.52

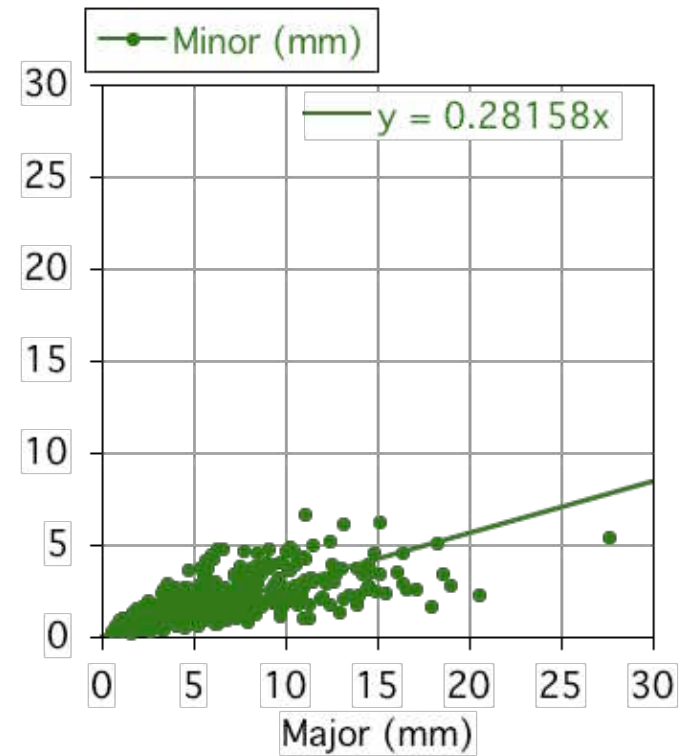
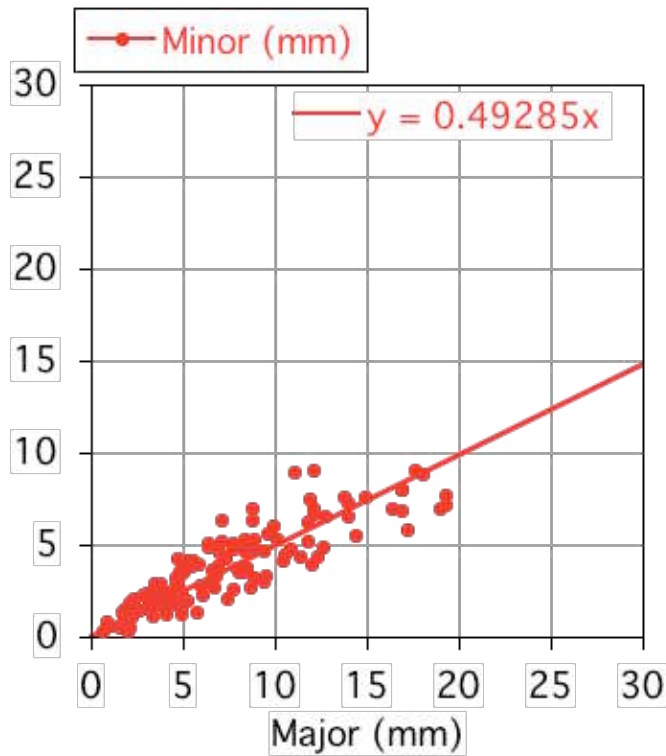
measures of size

measures of shape

Note: average (a/b)  $\neq$  1/average(b/a)  
 $1/0.56 = 1.78 \neq 1.98$   
 $1/0.37 = 2.7 \neq 2.95$



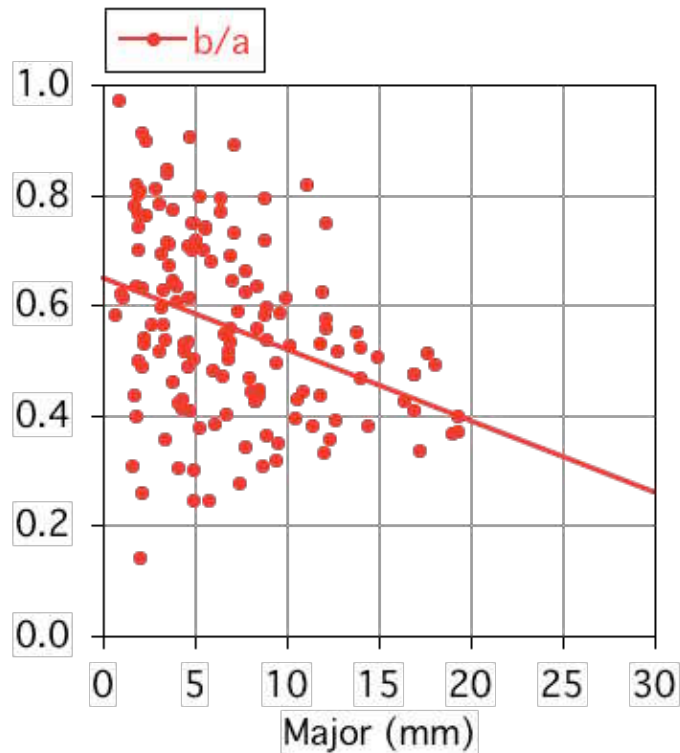
# more than one way to skin a cat...



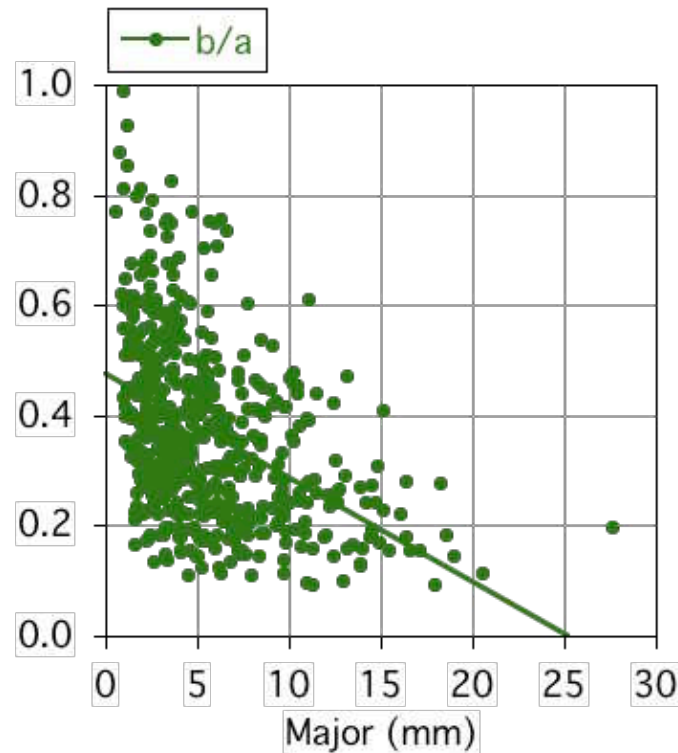
measures for axial ratio (= short / long)	garnet	omphacite
slope of Minor / Major	0.49	0.28
average (b / a)	0.56	0.37
l / (average (a / b))	0.51	0.30
average (h / w of Bounding Box)	0.56	0.37
l / (average (w / h of BoundingBox))	0.65	0.40

direct measures  
of axial ratio

# Size dependence of shape



$$y = 0.65063 - 0.012979x \quad R = 0.3513$$

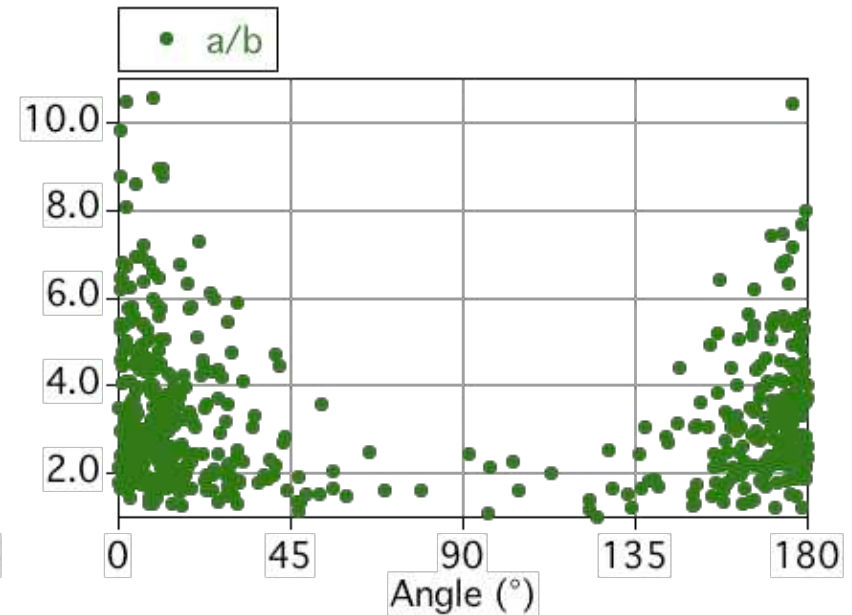
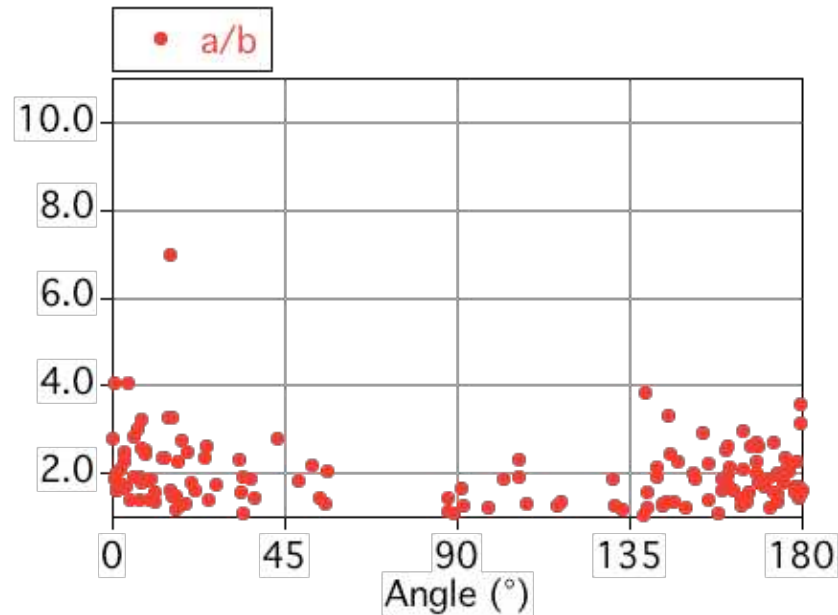


$$y = 0.47571 - 0.018866x \quad R = 0.43687$$

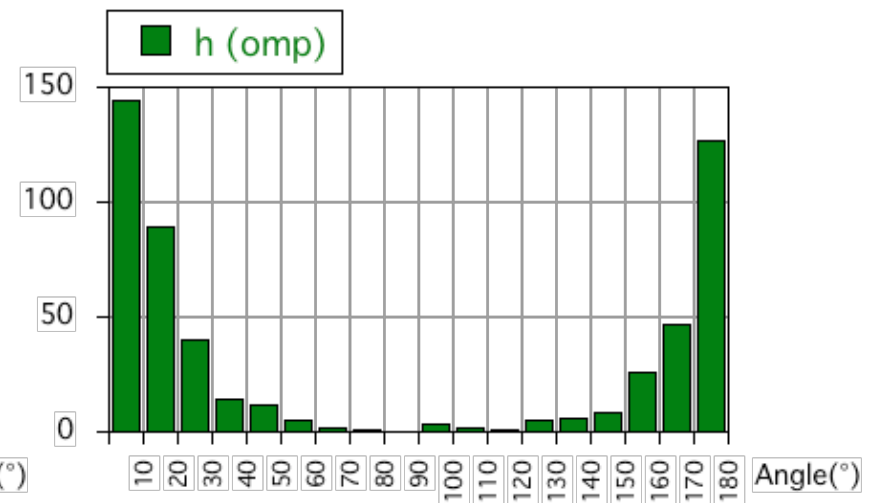
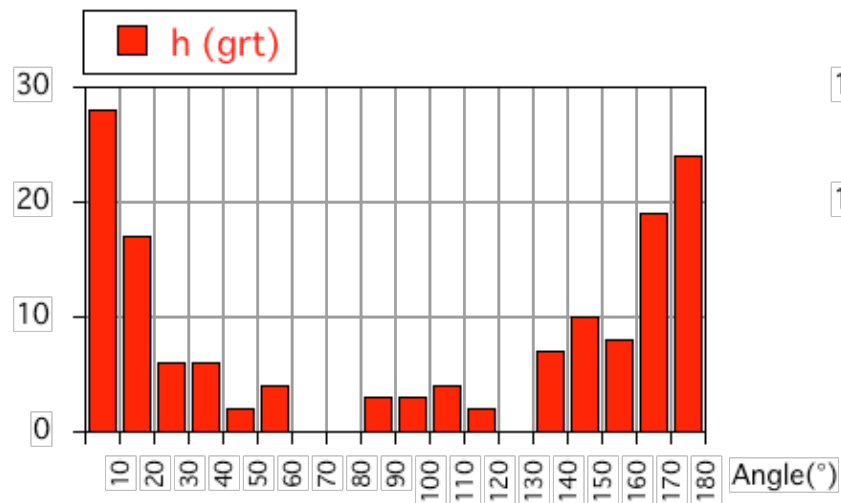
	garnet	omphacite
average of b/a for d > 10mm	0.48	0.25
slope of Minor / Major	0.49	0.28
slope of Minor / Major for d > 10mm	0.46	0.24
slope of Minor / Major for d < 10mm	0.55	0.33

# Orientation

$R_f / \varphi$  - plots

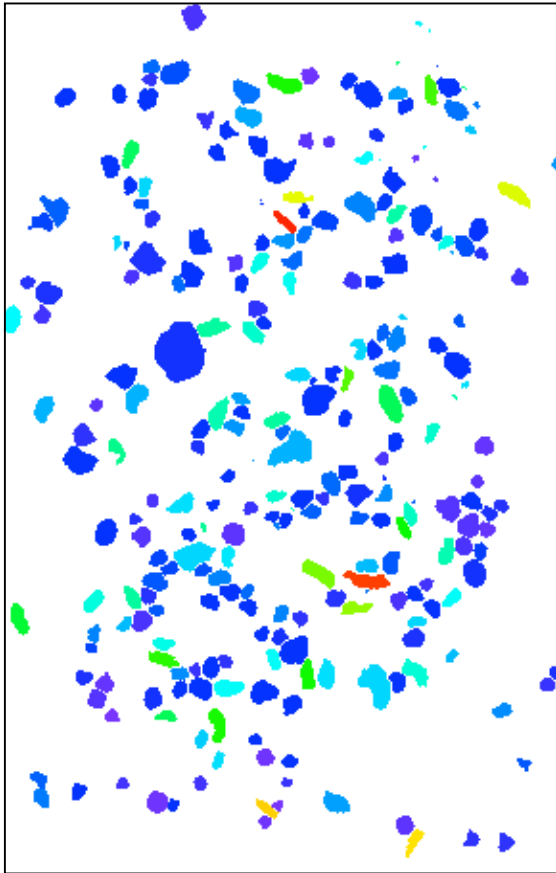


Histograms



# Übung 20 - Lazy grain mapping

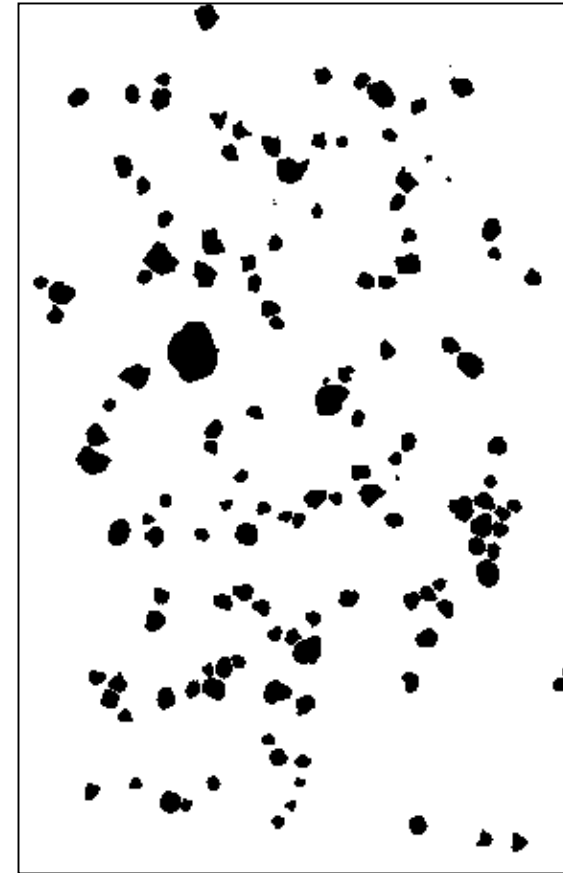
Geometrische Eigenschaften visualisieren



a/b

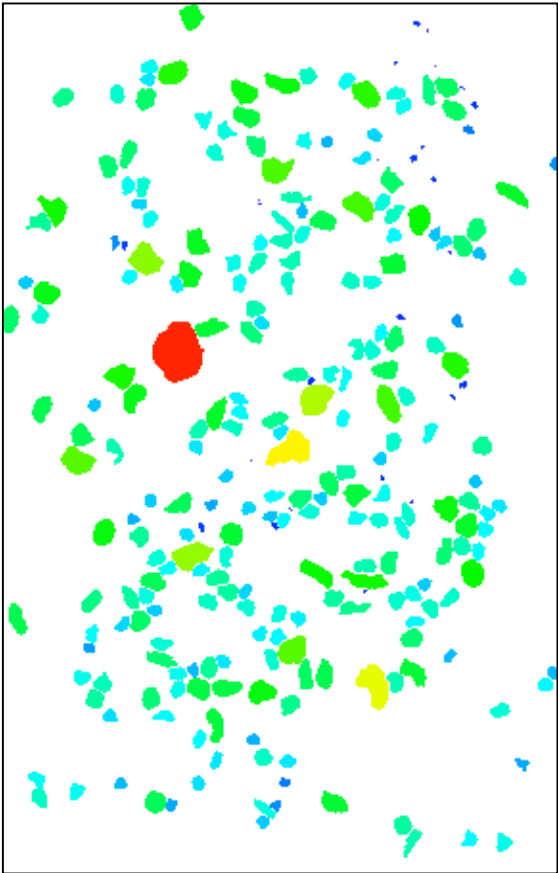


$a/b > 1.4$

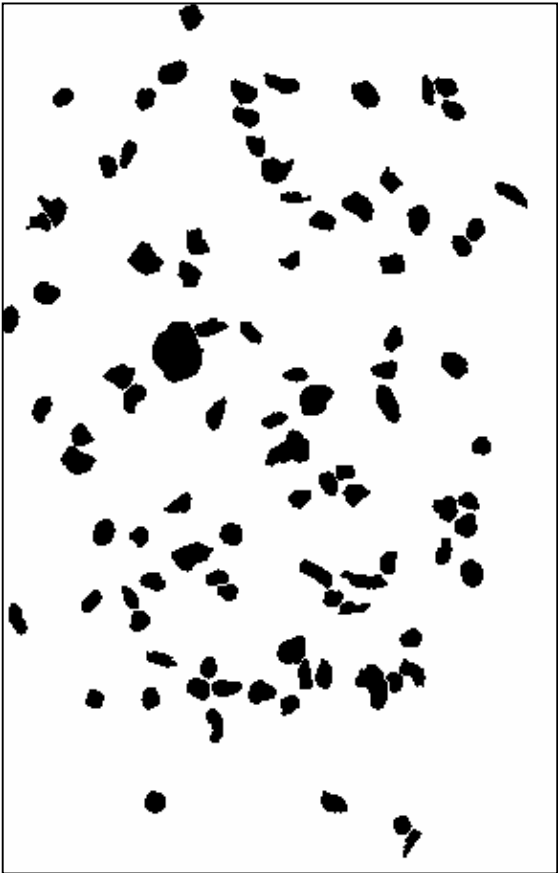


$a/b < 1.4$

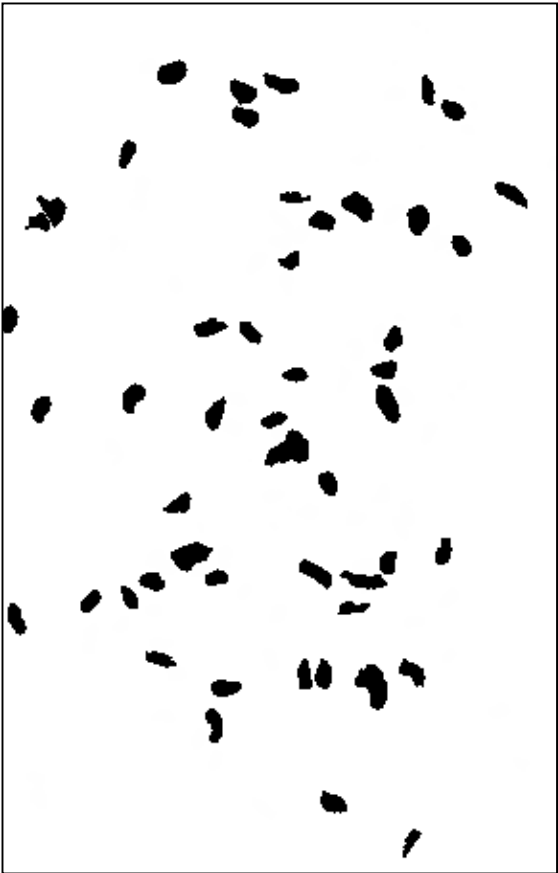
# combination



$r_{equ}$



$r_{equ} > 400\mu m$

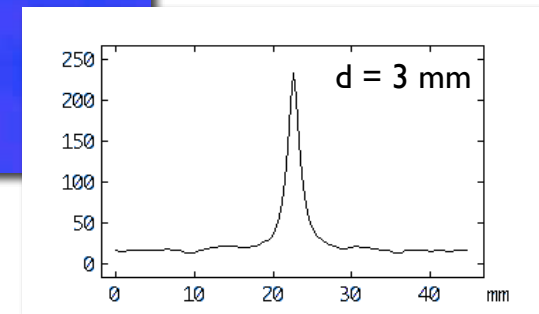
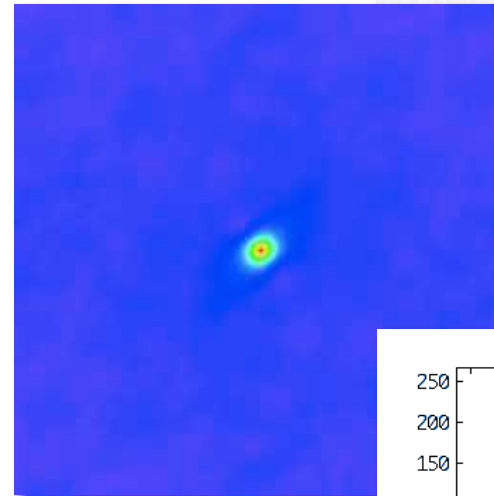
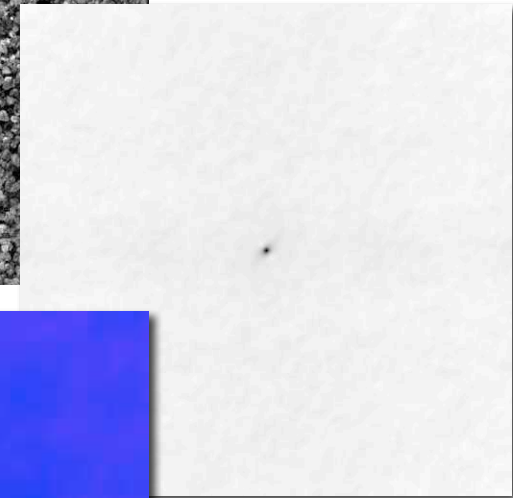
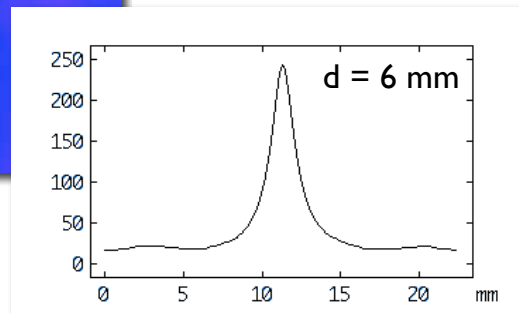
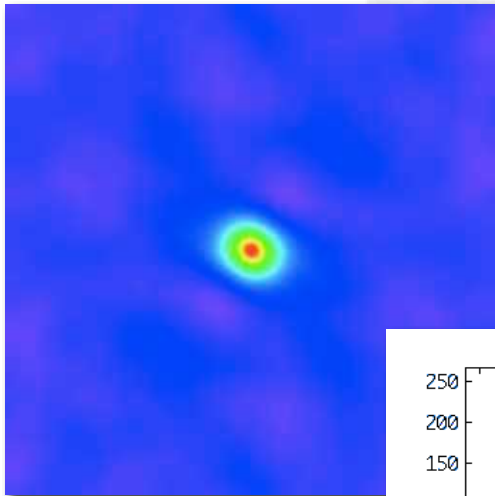
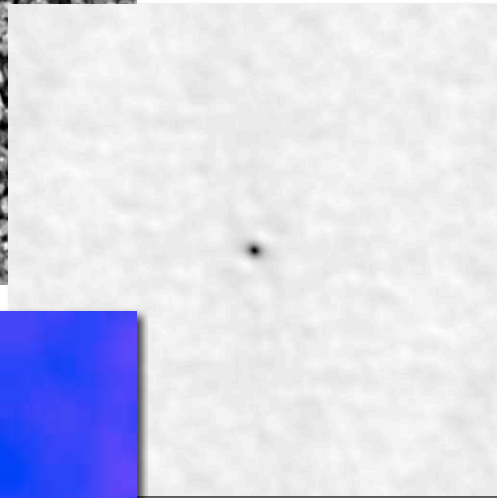
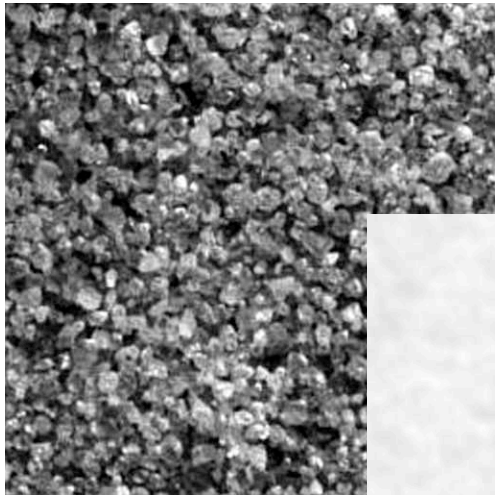


$(r_{equ} > 400\mu m) \cap (a/b > 1.4)$



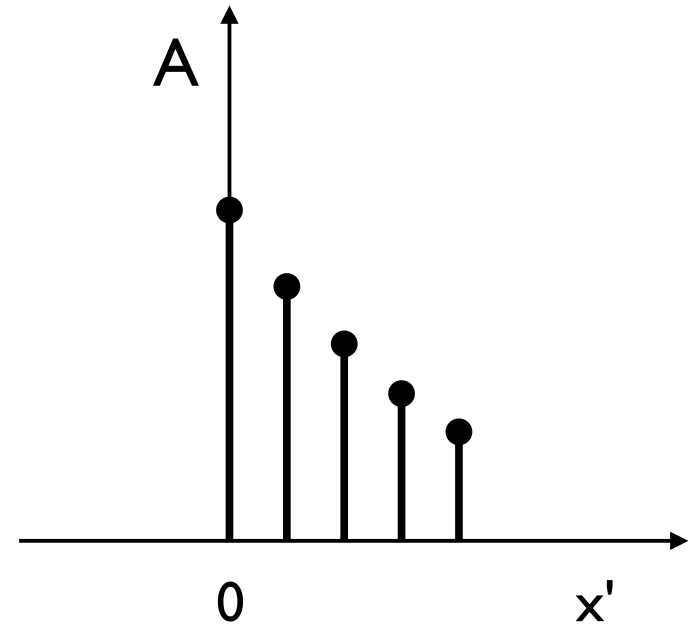
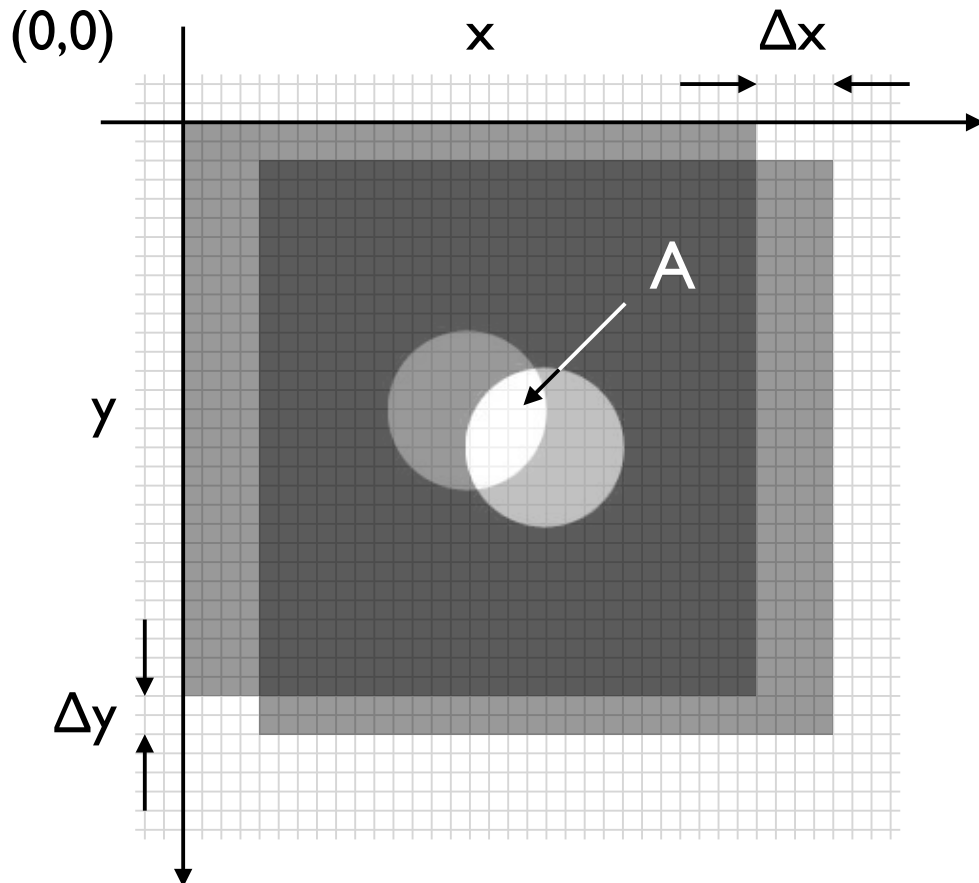
**ACF**

# Autokorrelationsfunktion wozu?



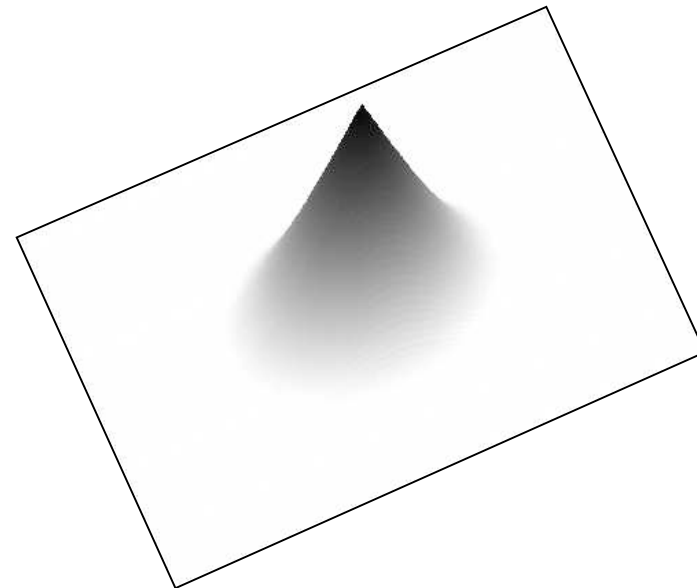
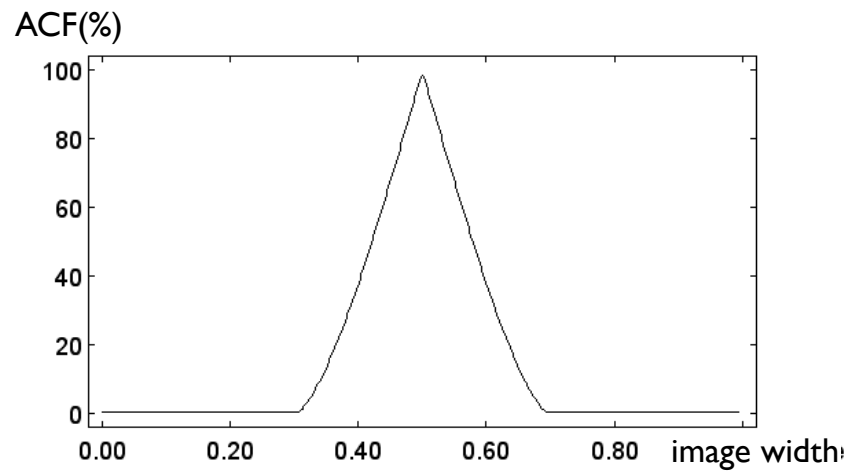
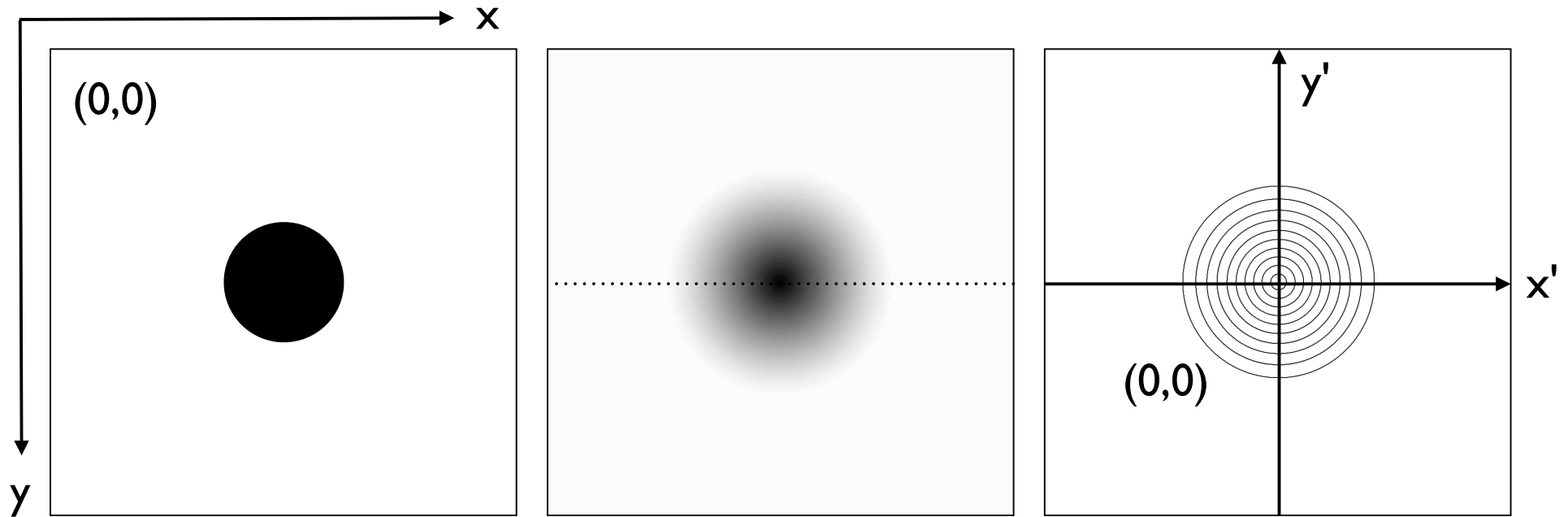
keine Segmentierung nötig :-)

# Autokorrelationsfunktion (ACF)

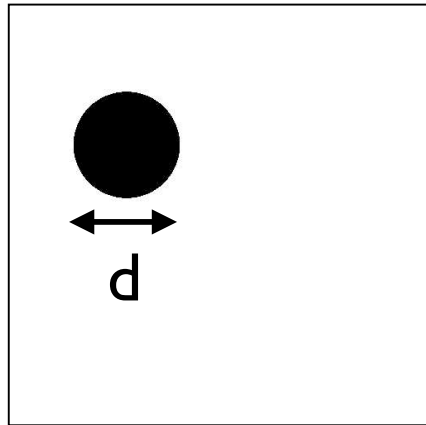


$$G(x, y) \otimes G(x, y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} G(x', y') \cdot G(x + x', y + y') dx' dy'$$

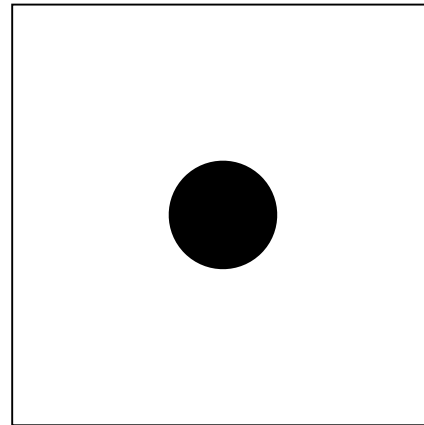
# Autokorrelationsfunktion (ACF)



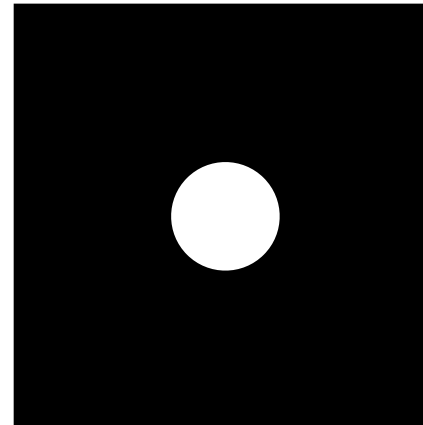
# Geometrische Eigenschaften



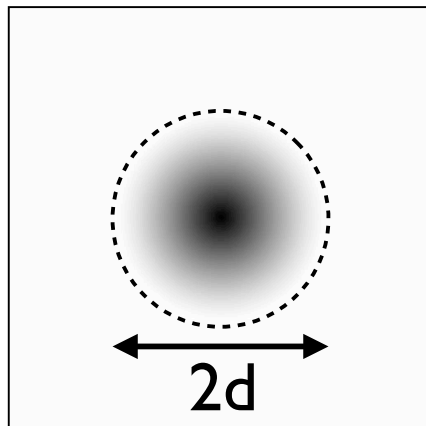
**a**



**b**



**c**



**d**

(a) Image of circle, diameter,  $d$ , indicated by double arrow;

(b) same circle as (a) moved to center;

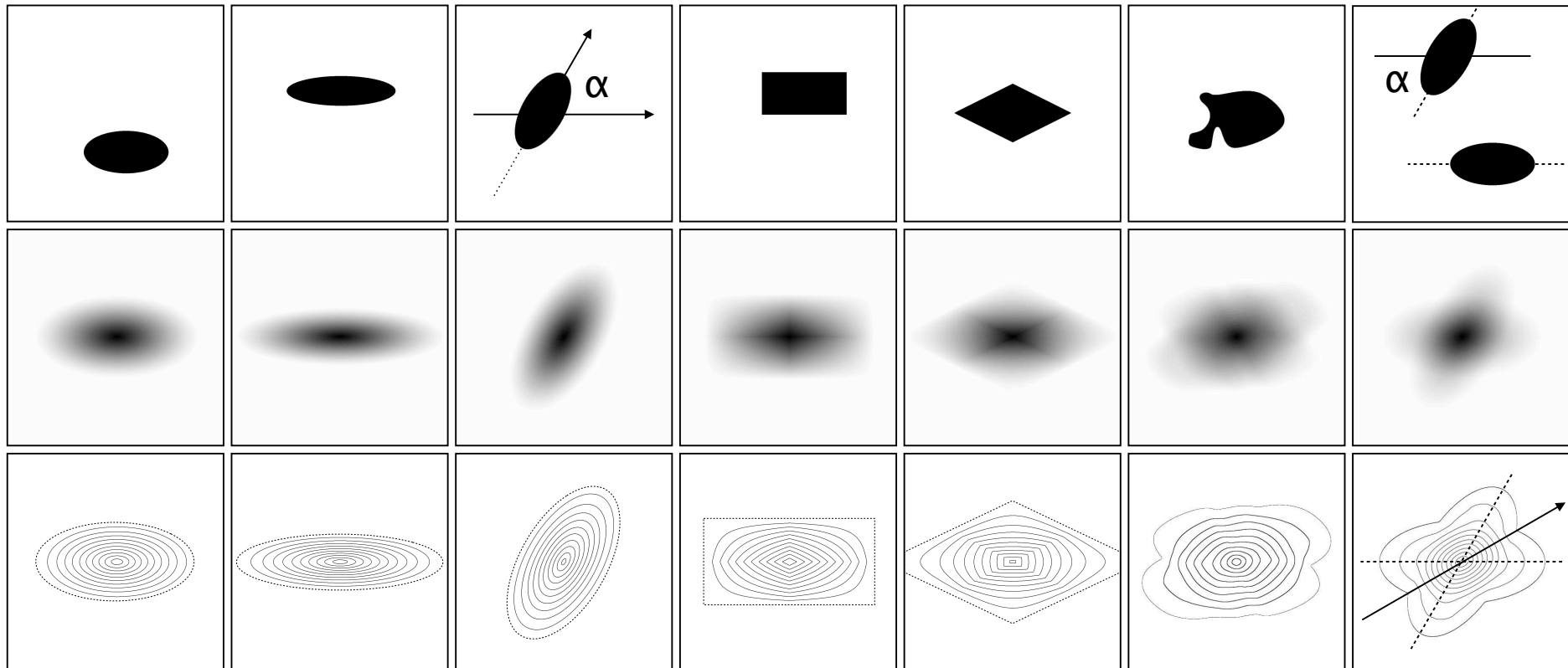
(c) same as (b) with inverted contrast;

(d) autocorrelation function (ACF) is the same for (a), (b) and (c); base line (where  $ACF = 0$ ) is indicated by stipples.

Note that the diameter of the base line is twice the diameter of the circle.



# Verschiedene Formen



Grösse

Achsenverhältnis

Einregelung

Form

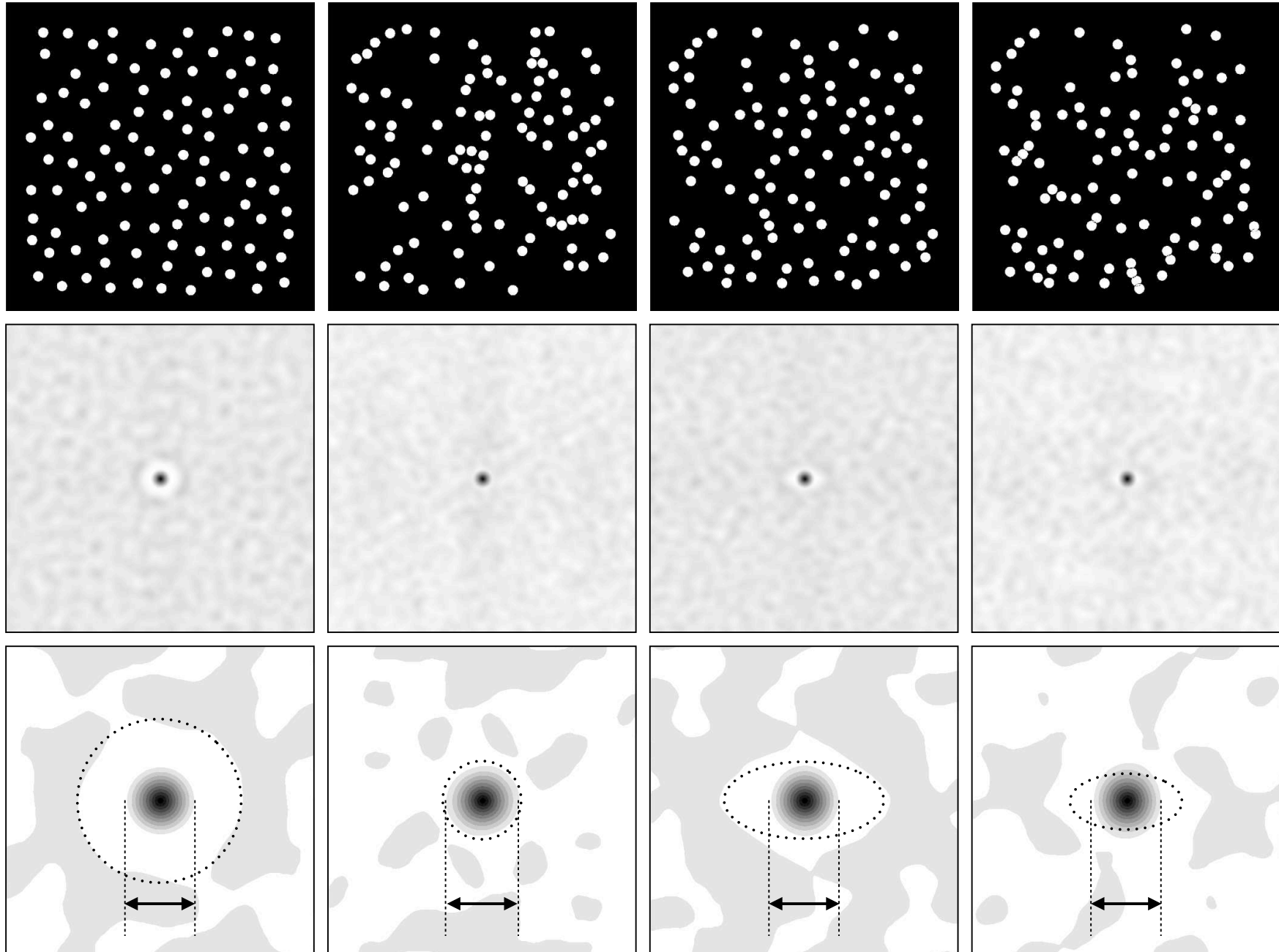
Korrelationslänge

Anisotropie

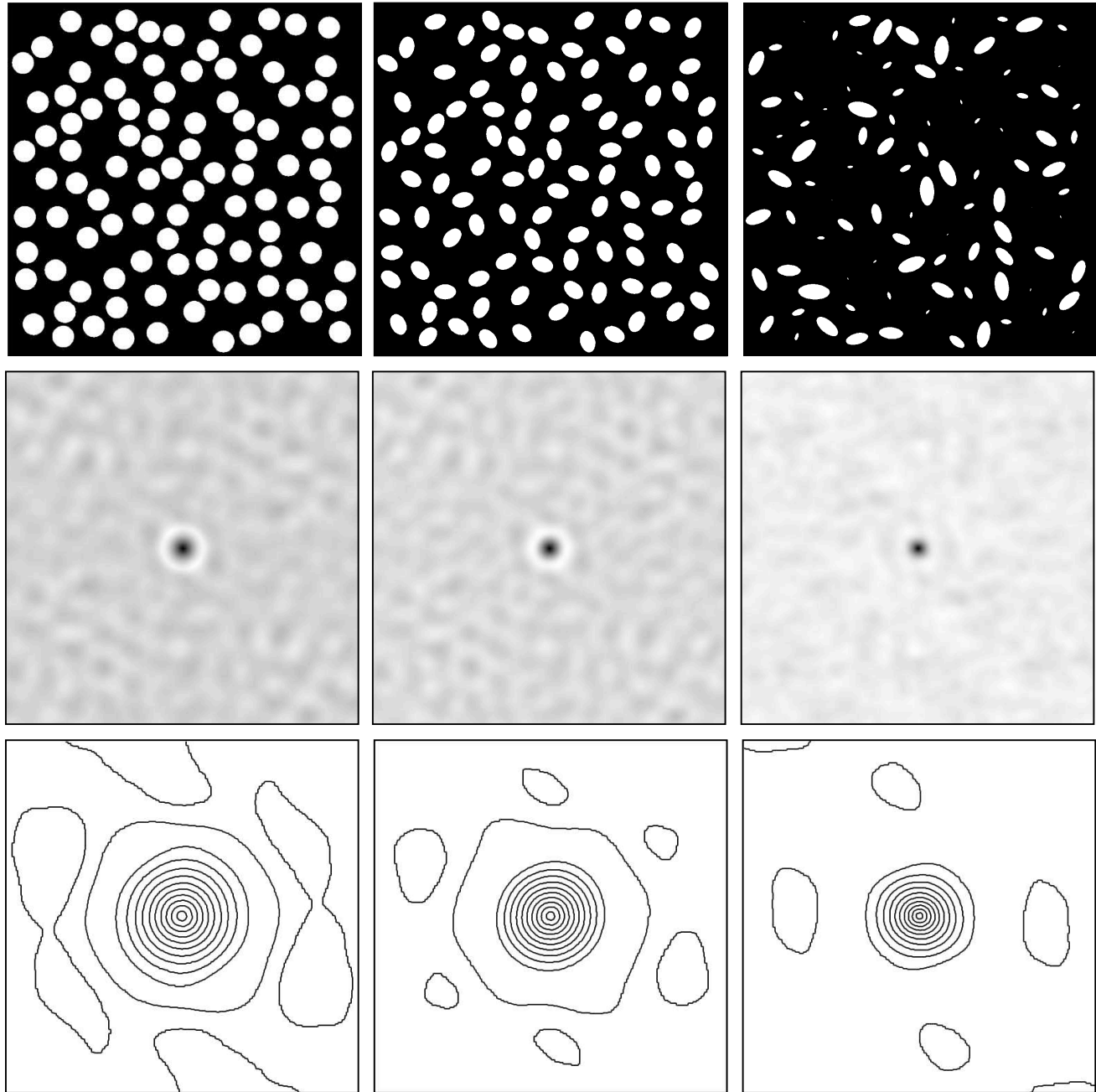
Orientierung

Symmetrie (orthorhombisch, monoklin)

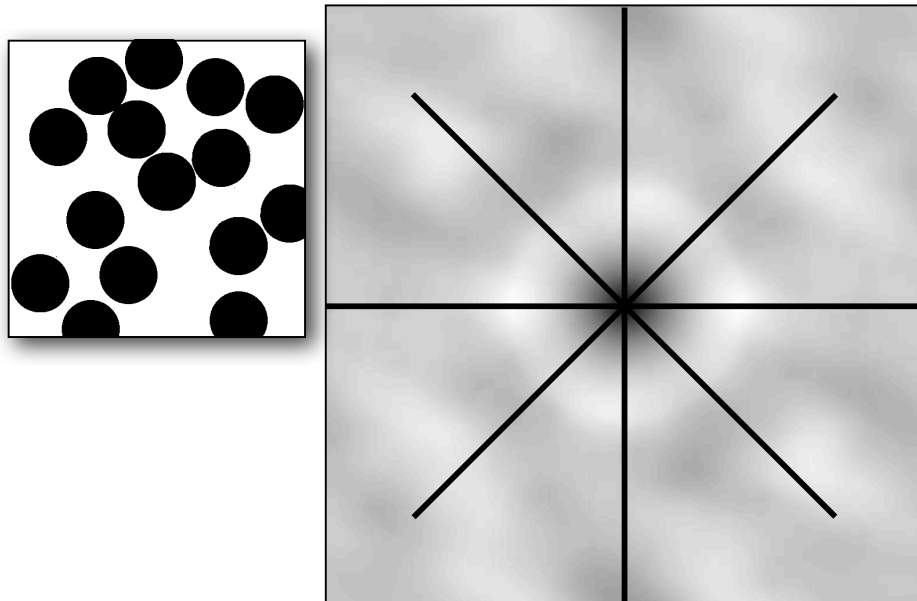
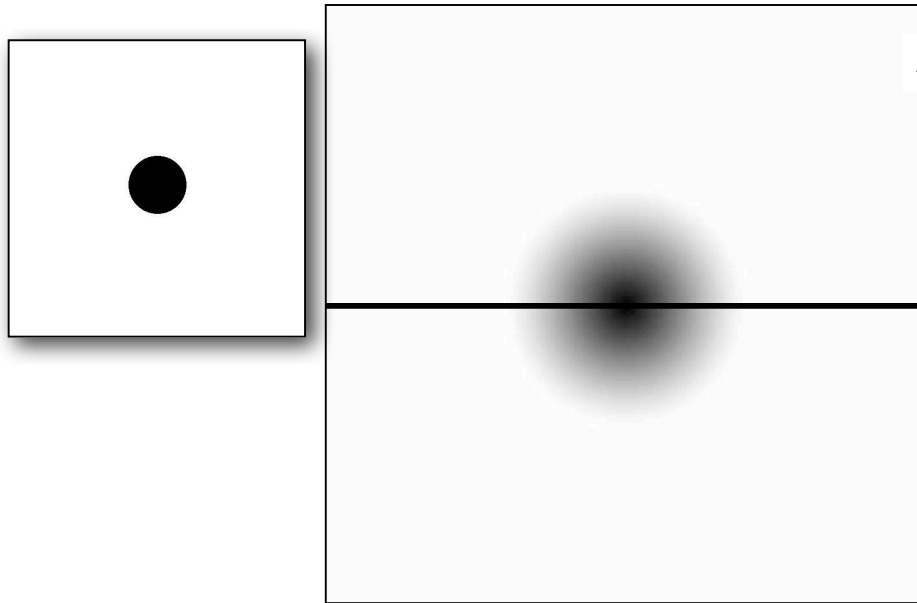
# Räumliche Anordnung



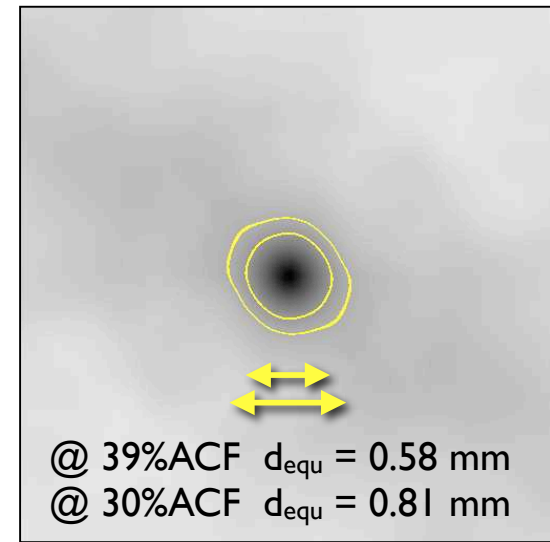
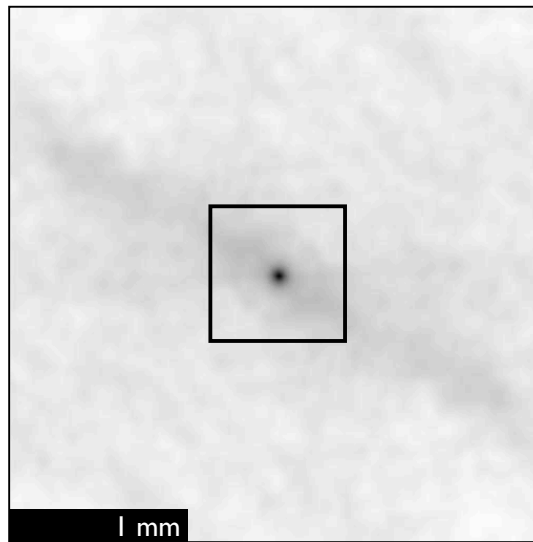
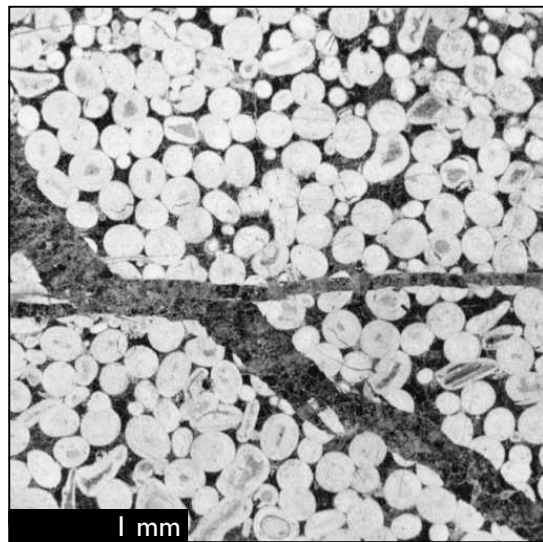
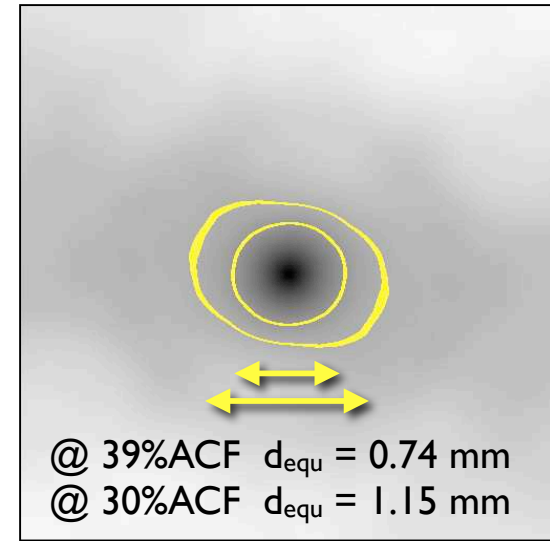
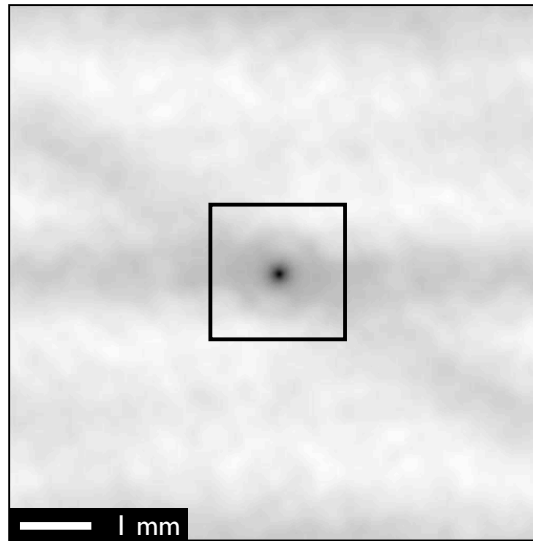
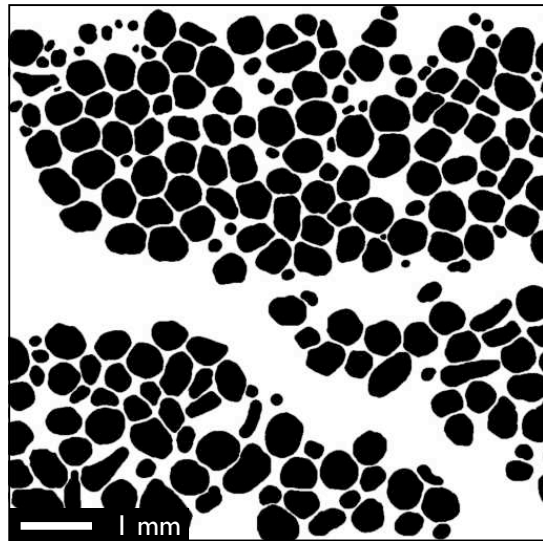
# Isotropie



# Korngrösse

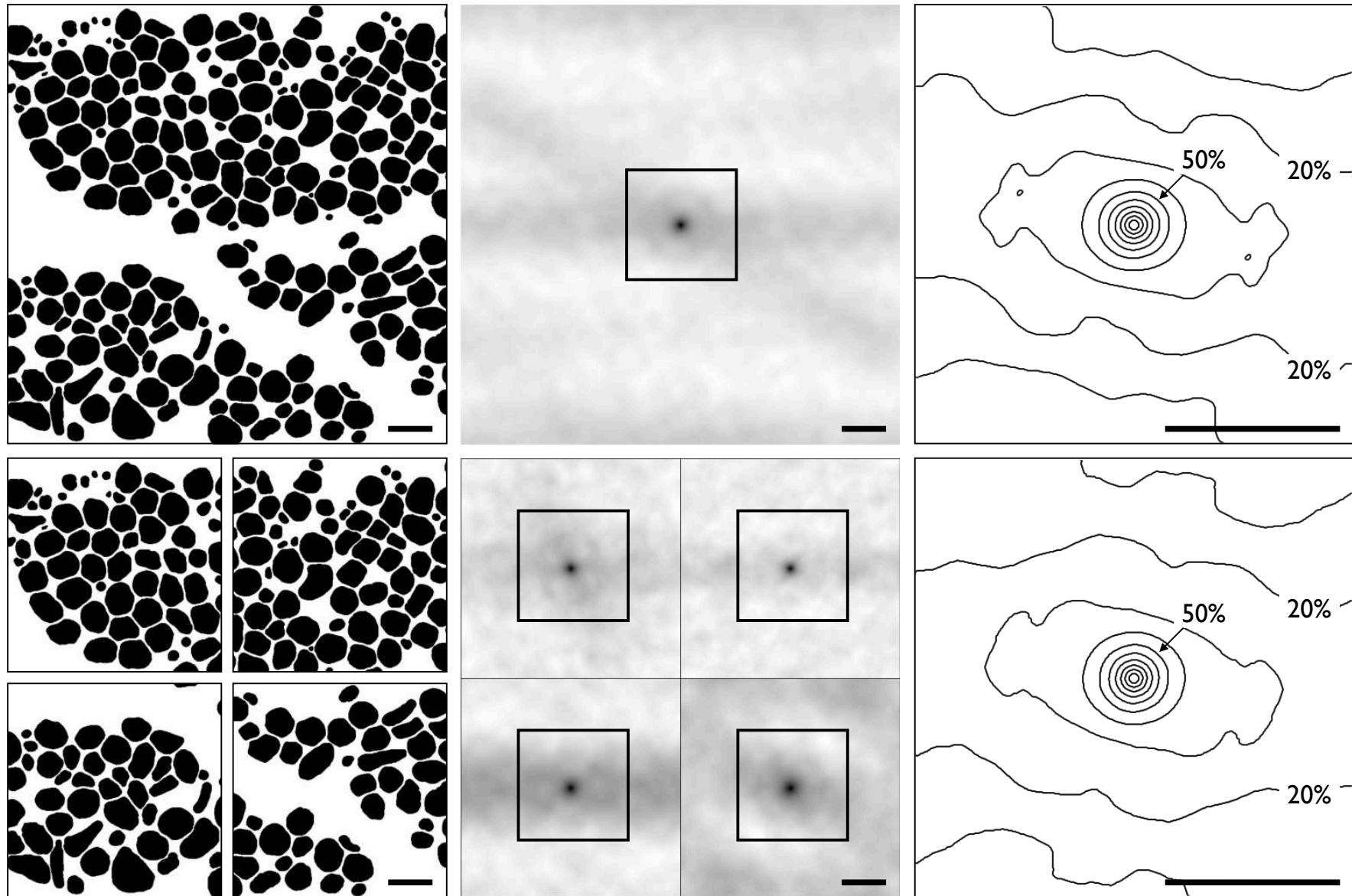


# Bitmap vs. Greyscale

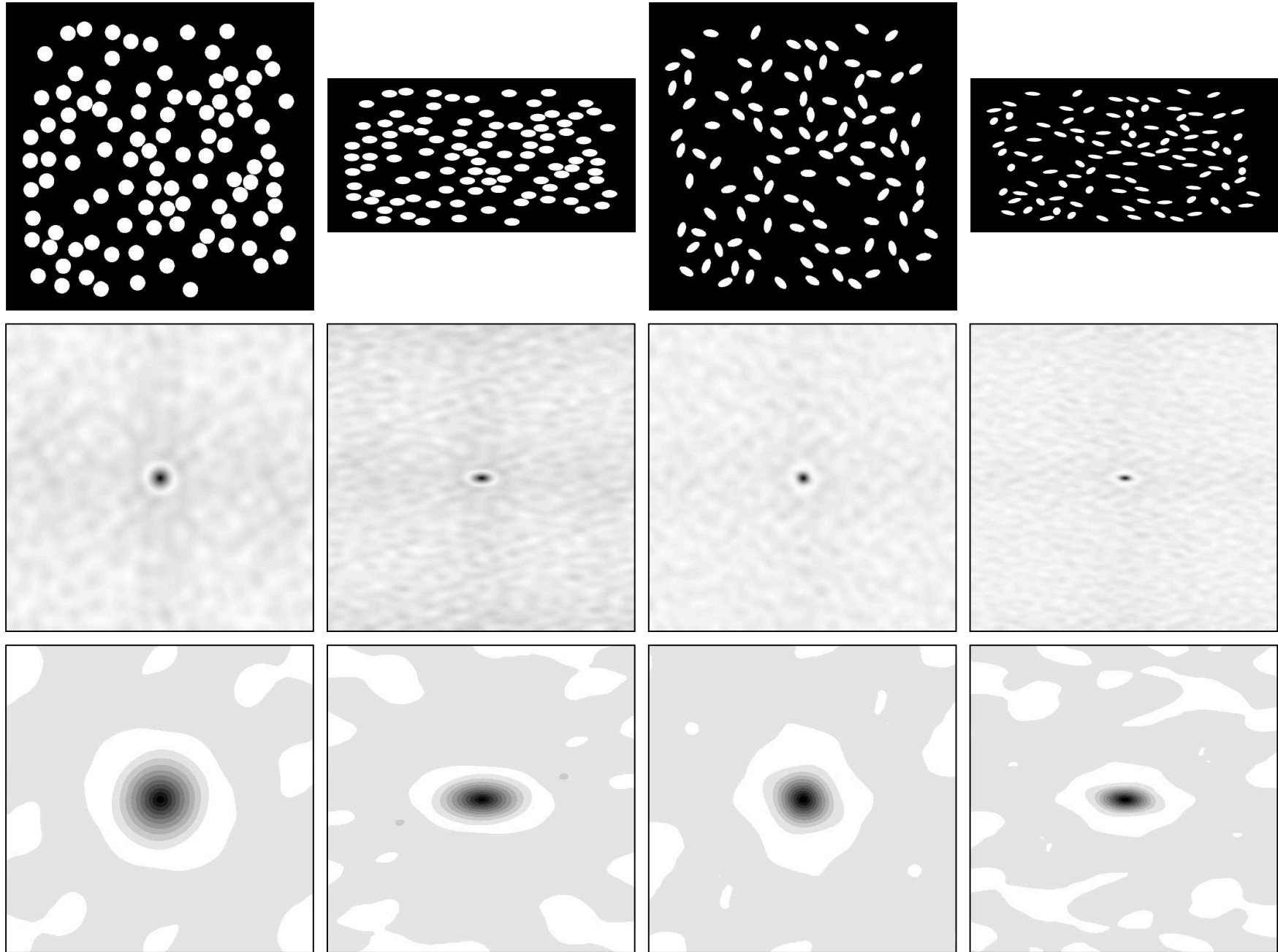




# Bulk ACF - tessellations



# Strain



# Übung 21 - ACF

## Autokorrelationsfunktion

Die ACF gibt Auskunft über Korrelationslängen, bzw. Grauwertstatistik.

Die ACF kann als Grauwertbild, als indiziertes Farbbild, als Surface Plot oder durch Profile dargestellt werden.

- Zwei Bilder (z.B. Misc0002.tif und Misc0003.tif) aus dem Ordner "texture selection 512\*512" öffnen und die ACF berechnen.
- Wodurch unterscheiden sich die ACFs der beiden Bilder.

# DBA 2014


## session 9

→ BASEL UNIVERSITY HOMEPAGE  
→ BASEL UNIVERSITY SCIENCE FACULTY (PHIL II)  
→ DEPARTMENT OF ENVIRONMENTAL SCIENCES  
→ GEOLOGICAL INSTITUTE

→ UNIBIB - Universitätsbibliothek  
→ URZ - Universitätsrechenzentrum  
→ VIA - Vorkursangebot  
→ RESEARCH - Personenseite

HOMER Contact Studium Geowissenschaften Lehrveranstaltungen Vorträge und Links Strukturgeologie  
Rock Deformation Projects & Software Workshops Textbook DDM Macros ImageJ Macros ImageJ Examples

LEHRVERANSTALTUNGEN



...ceci n'est pas "L'appel des cimes" de René Mugnoz...

### 12019 - DIGITALE BILDANALYSE

Vorlesung mit Übungen (2 KP) \* Herbstsemester 2010, 2012, 2014  
RENEE HEILBRONNER

**WO ?** Computerraum, Eingehölle, Bernoullianum

**ZIEL** Studierende sollen das Bildanalyse Programm NIHImage / ImageJ bzw. ImageJ kennenlernen, die Verwendung von Macros über (eventuell selbst schreiben), ein paar wichtige Verfahren zur Analyse von digitalen Bildern selbst ausprobieren, sowie deren Genauigkeit und Effizienz abschätzen. Kennenlernen der ImageJ Software (Mac/CSX)

**INHALT** Schwerpunkte dieser Vorlesung ist die digitale Bildanalyse, d.h. das computerisierte Erkennen und Quantifizieren von Bildmerkmalen. Computerprogramme bzw. Algorithmen für Pre-Processing, Segmentierung, Interpretation und Exportation (2-D- + 3-D) werden anwendungsorientiert vorgestellt. Methoden der Formanalyse, der Volumenschätzung sowie der Korngössenanalyse werden eingehend behandelt. Die Lehrveranstaltung ist auf die im akademischen Bereich sehr weit verbreitete Software ImageJ bzw. ImageJ (off public domain) abgestellt.

**LITERATUR**

- Heilbronner, R. & Barrett, S.D. (2013). Image Analysis in Earth Sciences. Springer Verlag. (Sammlungszählung möglich)
- Harterster, P. (1991). Digitale Bildverarbeitung, 4., durchgesehene Auflage. Carl Hanser Verlag, München, 404 S.
- Rosenfeld, A. & Kak, A.C. (1976). Digital Image Processing. Academic Press, New York, Computers & Geosciences Journal.

**INTERNET** [earth.unibas.ch](http://earth.unibas.ch)  
→ Phil II Geowissenschaften → 12019.01 - Digitale Bildanalyse

(← back)

TROMSDO GEOMAGING

→ TROMSDO CRUSTAL DYNAMICS HOMEPAGE (English)  
→ TROMSDO GEOLOGY HOMEPAGE (Norwegian)  
→ TROMSDO UNIVERSITY HOMEPAGE (English)

<http://earth.unibas.ch/micro/>

# Fragebogen

**Ergebniserhalt &  
Ergebnisrückmeldung**  
(1 Woche nach Evaluation)

Die Dozierenden erhalten die gescannten, ausgewerteten und in Berichtform aufbereiteten Ergebnisse ~~per E-Mail von der Studienkoordination~~ zugesendet. Die Dozierenden melden die zentralsten Ergebnisse den Studierenden nach Möglichkeit im Plenum zurück. Sie nutzen die Gelegenheit ggf. für Kommentierungen, ~~das Stellen vertiefender Fragen~~ oder zur Information über geplante Massnahmen. Die Dozierenden können zur besseren Verortung Vergleichslinien (Durchschnitts- oder Eigenvergleich über Zeit) in den Ergebnisbericht einzeichnen lassen. Wenden Sie sich bei Interesse an die Studienkoordination.



# Drum und dran

zu verbessern wäre:

## Thema der VL

Vorlesung in Kontext bringen, warum nur Geologie?

\* Es wird vertieft auf Algorithmen eingegangen ohne das klar wird warum man ein Stein untersuchen sollte

## Literatur

Vorlesungsunterlagen → sind nicht selbsterklärend, man braucht das Buch dazu um alles zu verstehen mehr man mal rechnet hat

## Beilagen (≠ Script)

Folien zur Vorbereitung zu spät hoch

in den

# Tempo

zu verbessern wäre:

Stoff wird sehr schnell vermittelt → mehr Zeit zum Verstehen geben.

2 Pausen machen, oder Pause genau in der Hälfte der 3 Stunden

zu schnelleres Vorbringen der Dozentin

# Übungen

zu verbessern wäre:

Man könnte die Vorlesung ein wenig kürzen und dafür mehr Übungen zu den Themen machen. Die Übungen vielleicht mit detaillierteren Schritt-für-Schritt-erklärungen,

Auftrag in Übungen etwas konkreter stellen.

Die Übungen besser beschreiben, damit man sie zu Hause besser nacharbeiten kann

allerdings:

dass die Übungen direkt miteinander gelöst werden

Ich finde es gut, dass immer ein Assistent dabei ist, um bei den Übungen zu helfen.

# Semesterfahrplan: Fahrplanänderung

			Freitag CR 14-17	Montag CR 14-17	
	Thema	Doz.	Gruppe A	Gruppe B	
1	Images for image analysis - intro: ImageSXM	RH	19-Sep-2014	22-Sep-2014	
2	Digital Images - Pixels - LUTs	RH	26-Sep-2014	29-Sep-2014	
3	Explore / pre-process digital images - intro: imageJ	RK	3-Oct-2014	6-Oct-2014	
4	POP segmentation - post-processing	RK	10-Oct-2014	13-Oct-2014	
5	Mathem./Punkt-Operationen Verschneide-Operationen	RH	17-Oct-2014		
		RH		27-Oct-2014	
	(fällt aus)				
			nur Freitag CR 14-17		
6	Filtern - Kantendetektion - NOP segmentation	RH	7-Nov-2014		
7	Analyze: segments - best-fit ellipses - property maps	RH	14-Nov-2014		
8	Fourier-Transformationen Autokorrelation	RH	21-Nov-2014		
9	<div style="background-color: yellow; border: 1px solid black; padding: 5px;"> <b>Besprechung des Probetests</b>  <b>Vertiefen des Stoffes anhand von weiteren Beispielen</b> </div>				
Test					

pro Nachmittag: 1. Teil: Vorlesung (Einführung in das Thema) - 2. Teil: Übungen  
 Besprechung der Übungen am Anfang der nächsten Vorlesung

# minitest

Auf Ihrem Computer befindet sich der Ordner "TEST\_21\_11\_2014".  
Darin befinden sich ein weiterer Ordner "Bilder" und ein Powerpoint File.

Schritt 1: Bitte benennen Sie den Ordner um, beispielsweise in "TEST\_Felix\_Muster" (falls Sie Felix Muster heissen...).

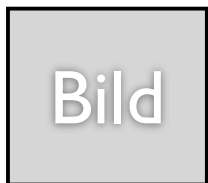
Schritt 2: Lösen Sie die Aufgaben im Powerpoint File. Wenn Sie fertig sind, sichern Sie das File. Bitte hinterlassen Sie Ihren TEST-Ordner - inklusive "Bilder"-Ordner und Powerpoint-File - auf dem Desktop.

Die für die Aufgaben erforderlichen Bilder sind im Ordner "Bilder".

Es gilt:



roter Pfeil:  
hier schreiben Sie bitte die Antwort hin.



grauer Platzhalter:  
Legen Sie das erforderliche Bild in Ihrem Ordner ab und schreiben Sie den Bildnamen in das Feld.  
Eventuell sind mehrere Bilder / Lösungen möglich. Speichern Sie alle.



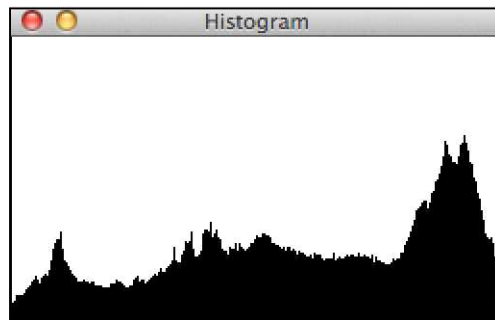
# (I) Bildunterschiede

Öffnen Sie die beiden Bilder Knockan.tif und KnockanI6.tif.

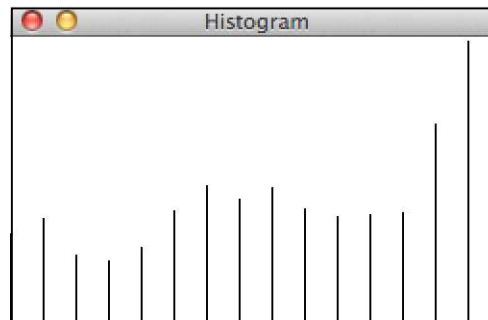
Worin unterscheiden Sie sich?

- ➔ Knockan.tif hat 256 Grauwerte: min= 0 max = 255 average = 148.96 (58%)  
KnockanI6.tif hat 16 Grauwerte: min= 0 max = 255 average = 150.42 (59%)

Stellen Sie den Unterschied bildlich dar.

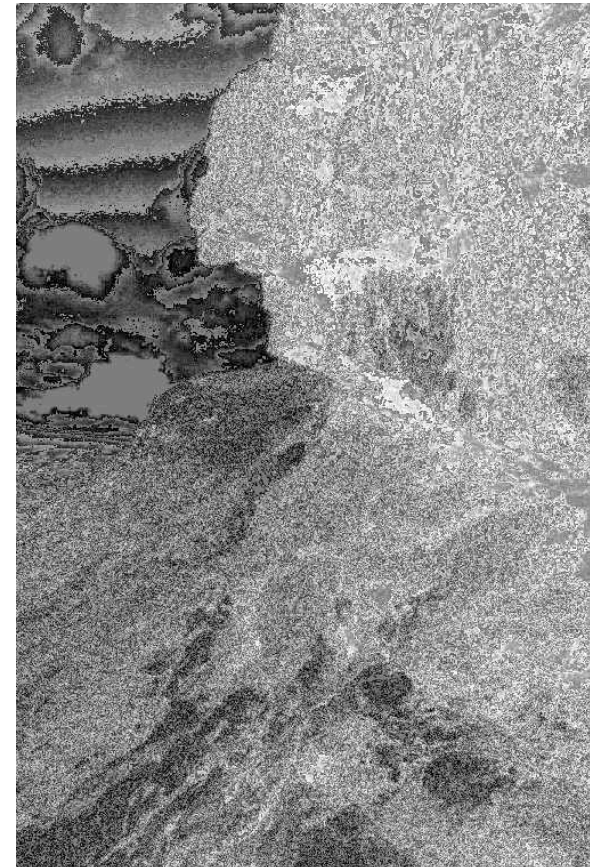


Knockan.tif



KnockanI6.tif

KnockanDiff.tif =  
Knockan.tif - KnockanI6.tif

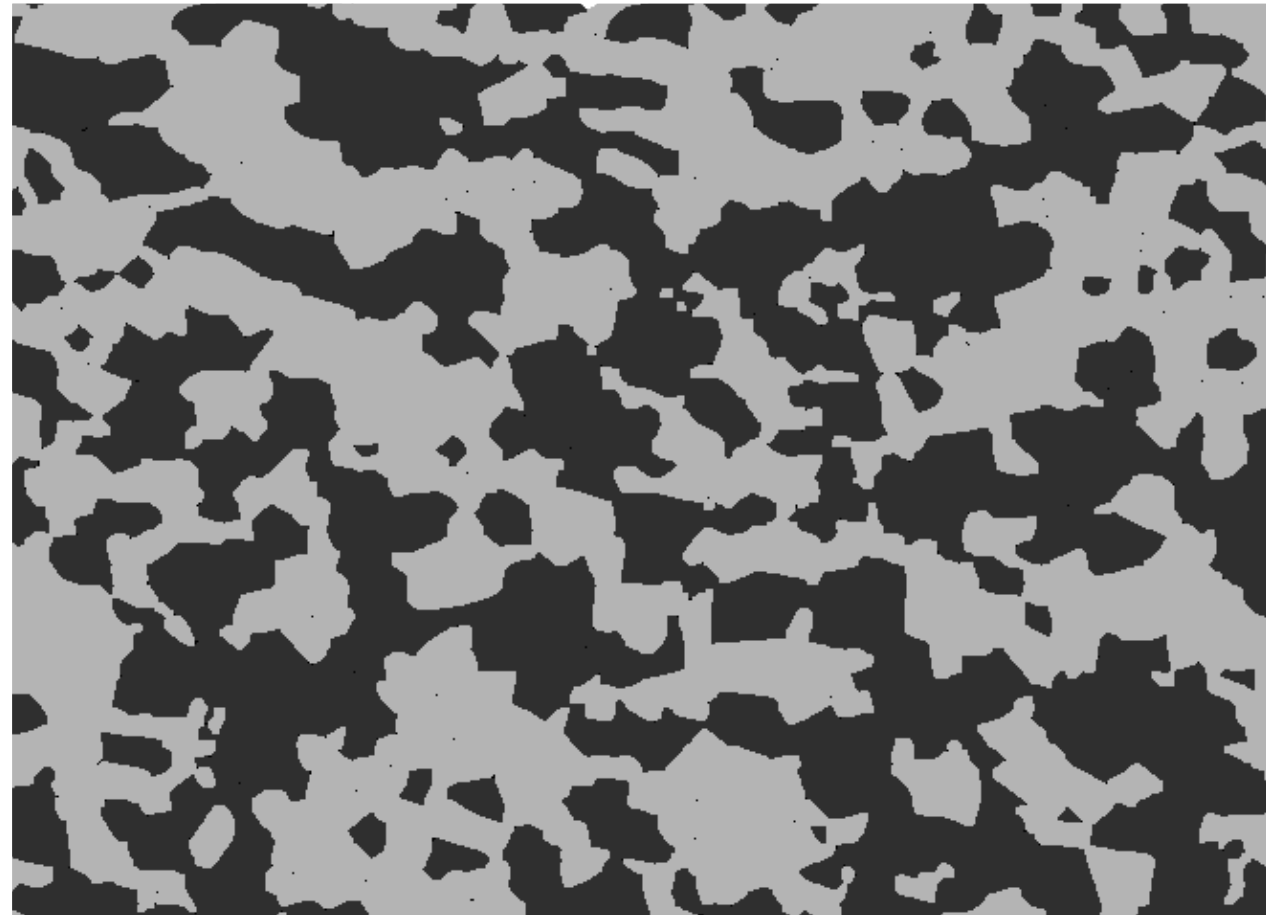


## (2) Bildanalyse I

Öffnen Sie das Bild cc-anh-50-50.tif. (Masstab = 100 $\mu$ m) (hell= Anhydrit dunkel = Kalzit)

(1) minimum filter to obtain phases - no boundaries

(2) crop area for 100% coverage



cc-anh-50-50 crop.tif

## (2) Bildanalyse I



Öffnen Sie das Bild cc-anh-50-50.tif. (Masstab = 100 $\mu$ m) (hell= Anhydrit dunkel = Kalzit)  
I. Schritt: Scale image 50px = 100 $\mu$ m



Bestimmen Sie den Volumanteil von Anhydrit und Kalzit ( $V_{\text{Anhydrit}\%} : V_{\text{Kalzit}\%}$ )  
Density Slicing Tool - Measure - Resultat in Info window:  
anh = 51.6% cc = 48.3%



Bestimmen Sie die durchschnittliche Korngrösse ( $\mu$ m) von Anhydrit und Kalzit.  
average  $r_{\text{equ}}$  anh = 17.26 $\mu$ m n = 547  
average  $r_{\text{equ}}$  cc = 22.9 $\mu$ m n = 310



Bestimmen Sie die Anzahl Körner von Anhydrit und Kalzit.  
anh n = 547  
cc n = 310 (grössere Körner  $\pm$  gleich viel Volumen)



Welche Definition von 'Korngrösse' verwenden Sie?  
Radius des flächengleichen Kreises



Mit welchem Verfahren bestimmen Sie den Mittelwert ?  
in Kaleidagraph requ ausgerechnet ( $c2 = \sqrt{c1/\pi}$ ) und Functions > Statistics benützt

# (3) Bildanalyse 2

Öffnen Sie das Bild cc-anh-50-50.tif (Masstab = 100µm)

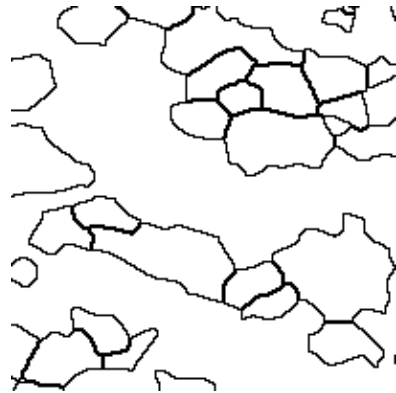
Stellen Sie je eine Karte mit den Kornoberflächen von Kalzit und Anhydrit her.

Option 1: Open - Duplicate - Rankfilter(Dilate) - XOR copy to grain map:

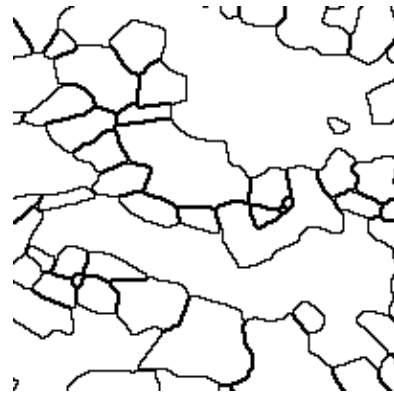
Option 2: use Binary > Outline

Files:

cc-outer.tif



anh-outer.tif (Ausschnitte)



Bestimmen Sie die relative Oberflächendichte von Anhydrit und Kalzit ( $S_{\text{Anhydrit}\%} : S_{\text{Kalzit}\%}$ )

Set threshold - Measure - read result in Info window



$S_{\text{Anhydrit}\%} : S_{\text{Kalzit}\%} = 6.923 : 9.466$  total = 16.389% image => 42% : 58 % Gesamtoberfläche

## (4) Bildanalyse 3

Öffnen Sie das Bild cc-anh-50-50.tif (Masstab = 100 $\mu$ m)

Berechnen Sie je eine Bitmap, welche alle Anhydrit- bzw. Kalzitkörner zeigt, deren Achsenverhältnis (aspect ratio  $a/b$ ) kleiner als 1.4 ist.

(a) Wieviele Körner erfüllen die Bedingung  
- im Fall von Kalzit - im Fall von Anhydrit?  
Analyze Particles - read result in Info window

anh n = 127 (von 547)

cc n = 107 (von 310)



(b) Wieviel Prozent sind das jeweils?

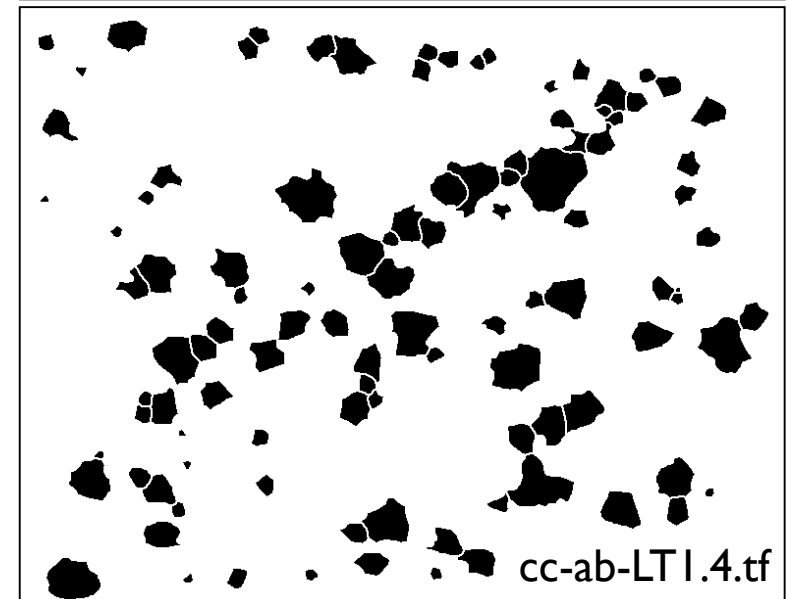
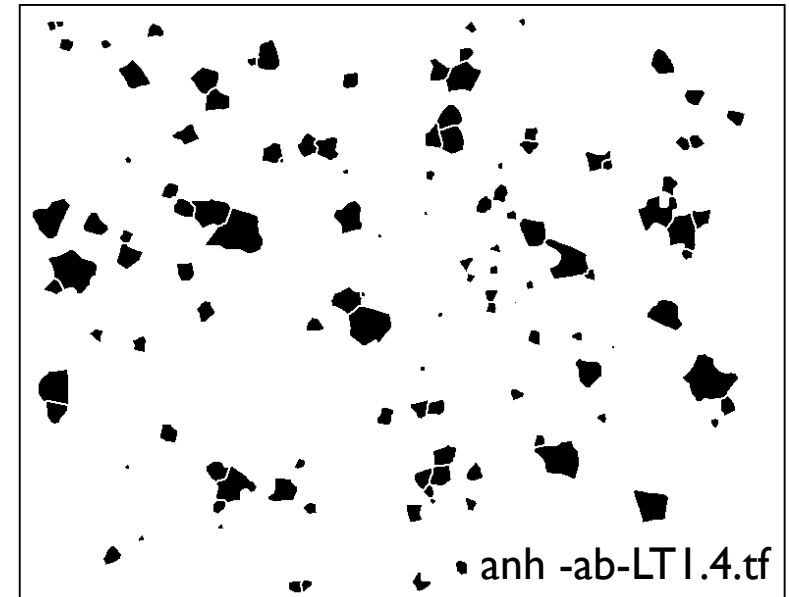
anh  $\approx$  23%

cc  $\approx$  35%



(c) Was bedeutet diese Resultat?

Im Durchschnitt sind die cc Körner eher runder,  
die anh Körner eher gelängt.





# (5) Filtern

Öffnen Sie das Bild Knockan.tif.

Schreiben Sie einen Filterkernel, welcher einen horizontalen Wisch-Effekt (motion blur) der Länge 11 pixel bewirken soll.



```
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 1 1 1
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0
```

Wenden Sie den Filter auf das Bild an



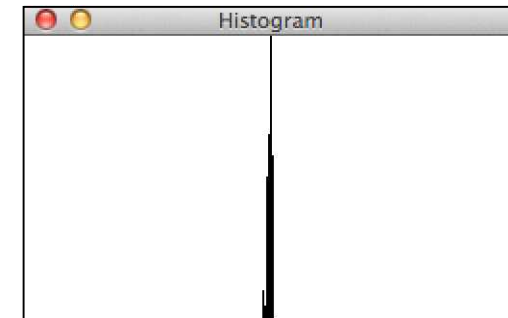
Detail von KnockanWisch.tif

# (6) Rätsel

Öffnen Sie das Bild WaslstDennDas.tif ...

... und beantworten Sie die Frage, die es stellt.

Welches Verfahren wählen Sie?

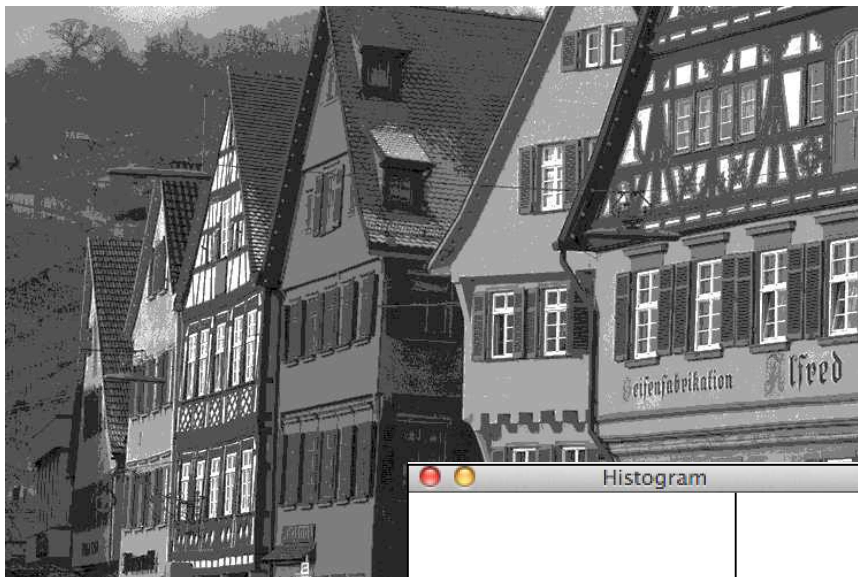


Original



Enhance Contrast

Equalize



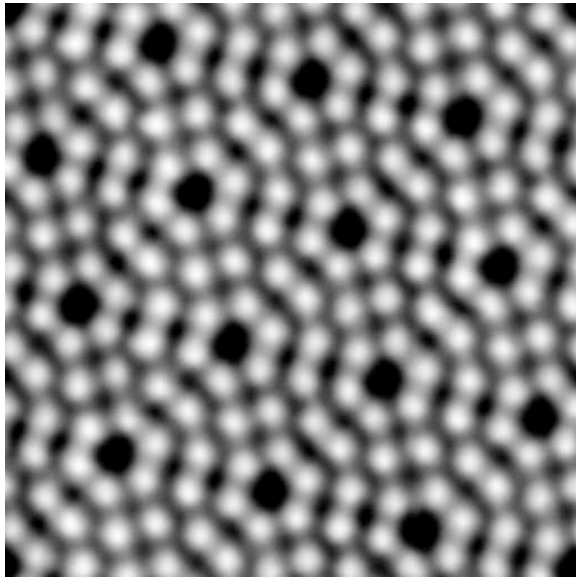
after Apply LUT



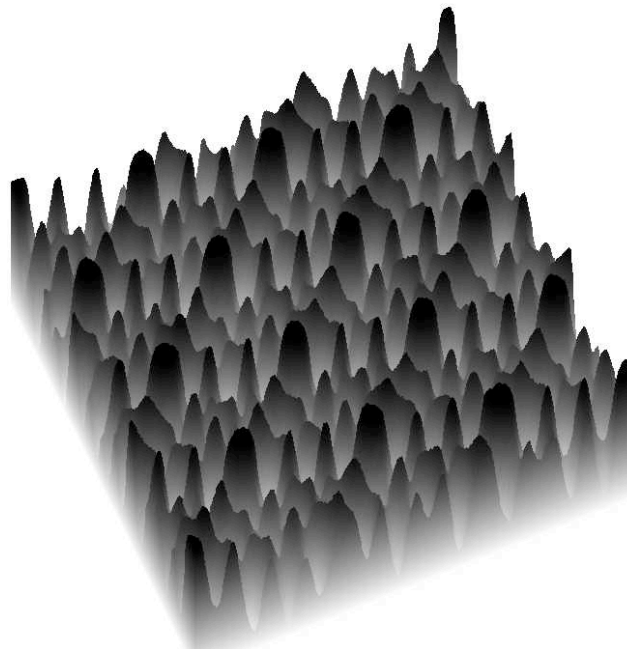
after Apply LUT

# ACF revisited

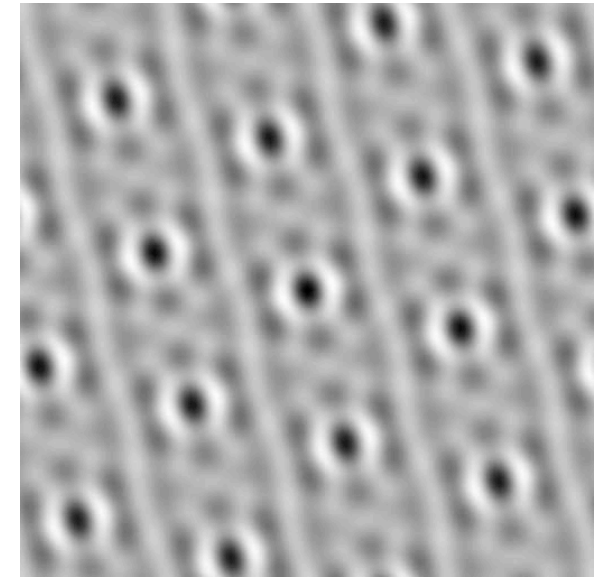
# recap ACF



original



original



ACF

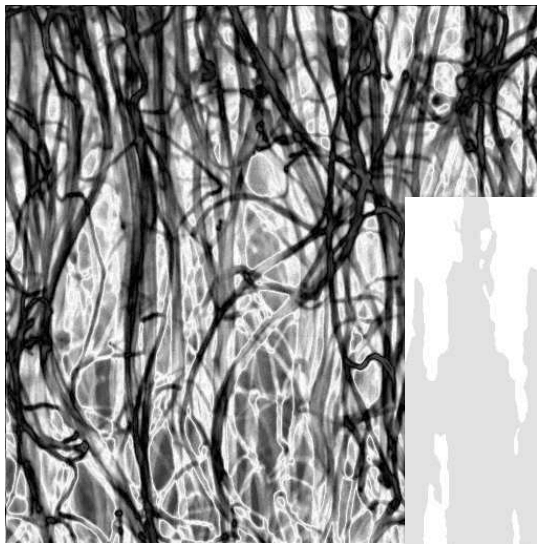
short distance (central peak)

(Korn-)Grösse  
Achsenverhältnis  
Einregelung  
Form

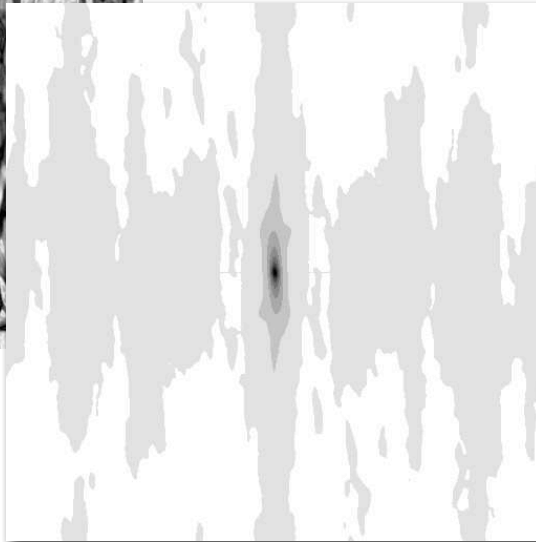
long distance (background)

Korrelationslänge  
Anisotropie, Konnektivität  
Orientierung  
Symmetrie

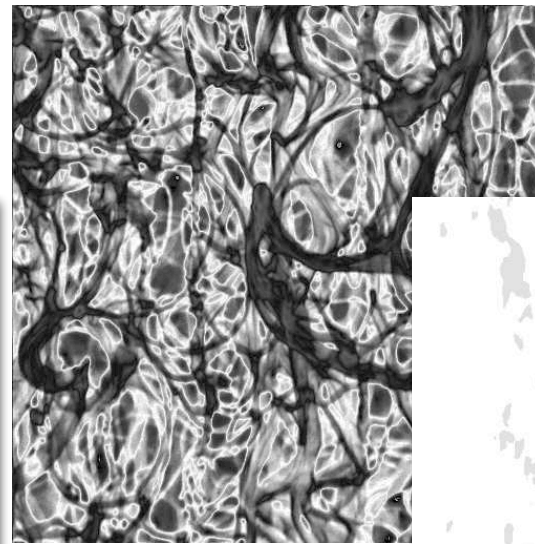
# recap ACF



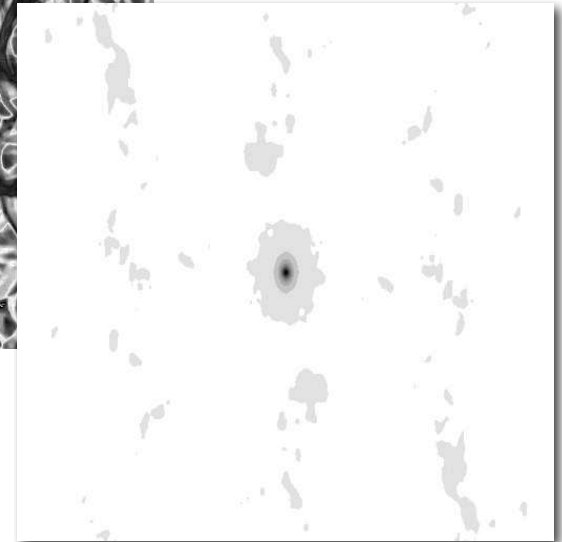
original



ACF



original



ACF

short distance (central peak)

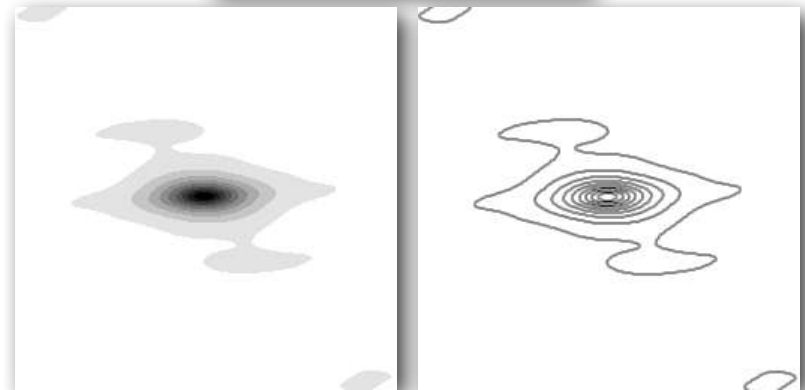
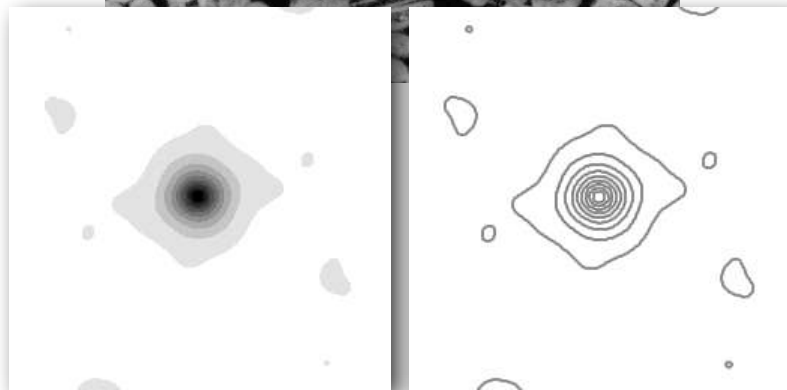
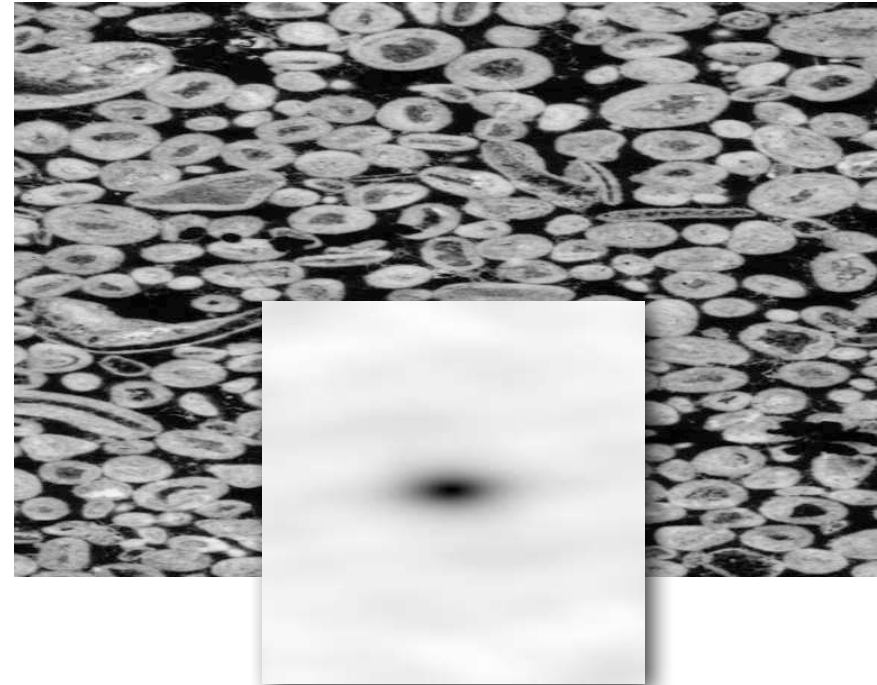
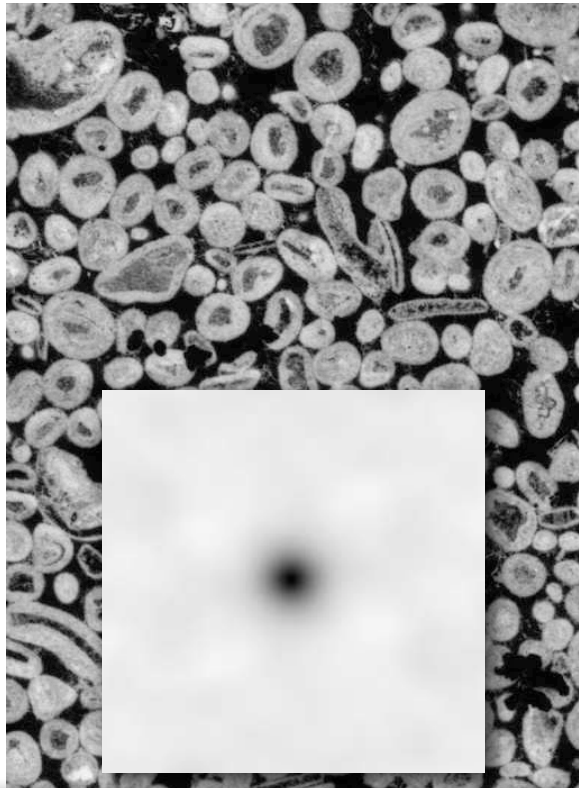
(Korn-)Grösse  
Achsenverhältnis  
Einregelung  
Form

long distance (background)

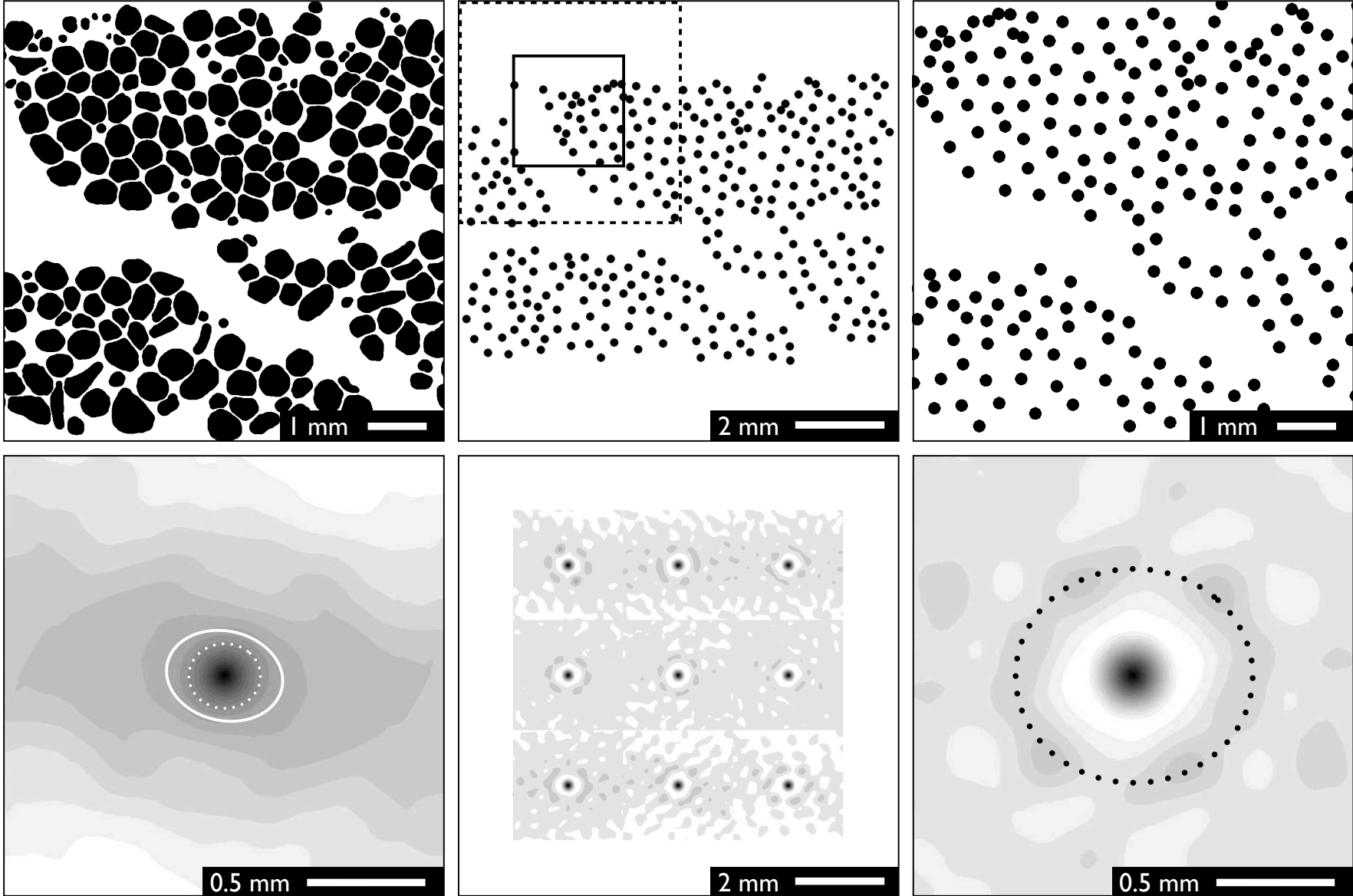
Korrelationslänge  
Anisotropie, Konnektivität  
Orientierung  
Symmetrie



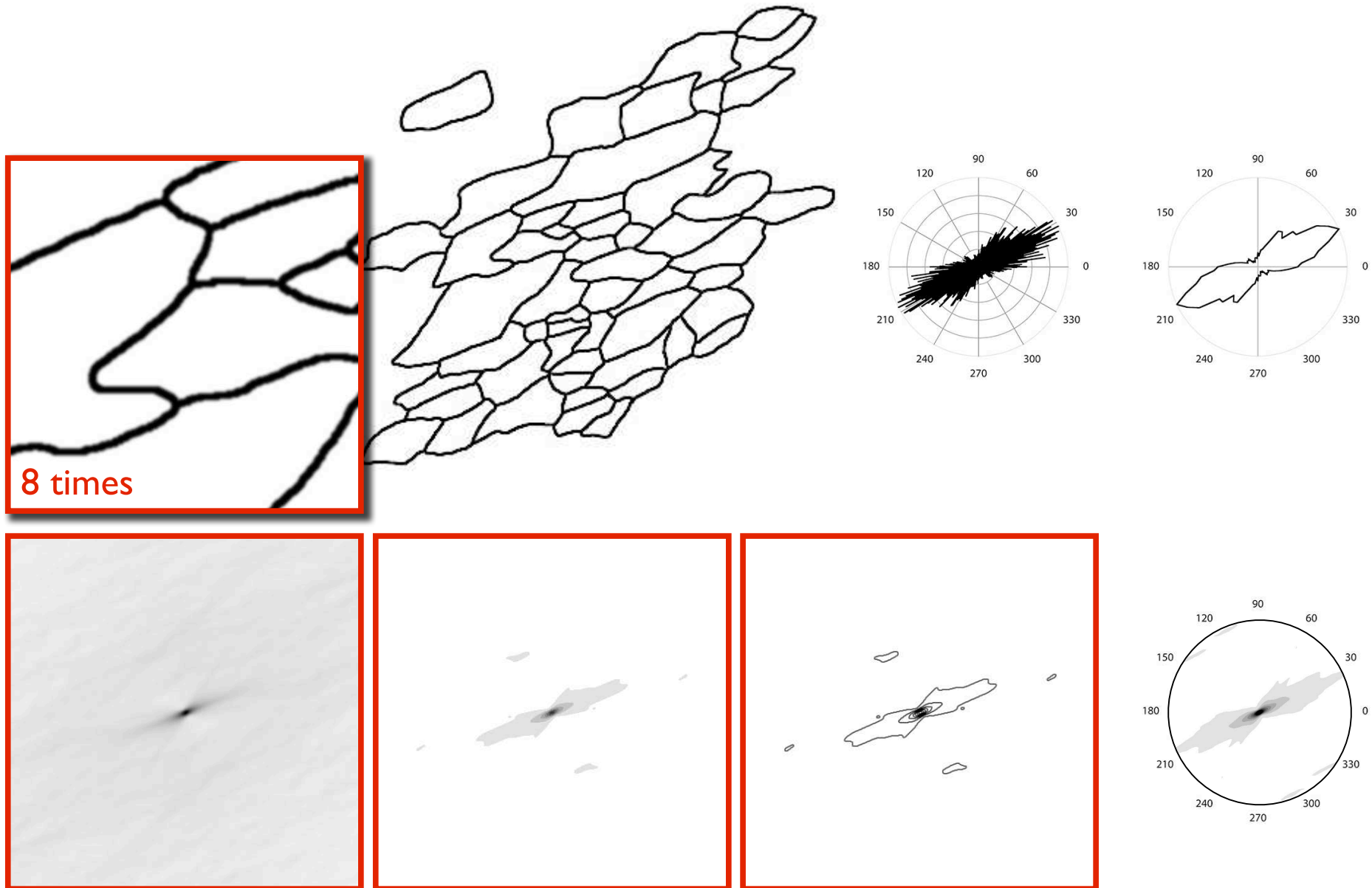
# recap ACF - Strain



# strain of center points - Fry plots

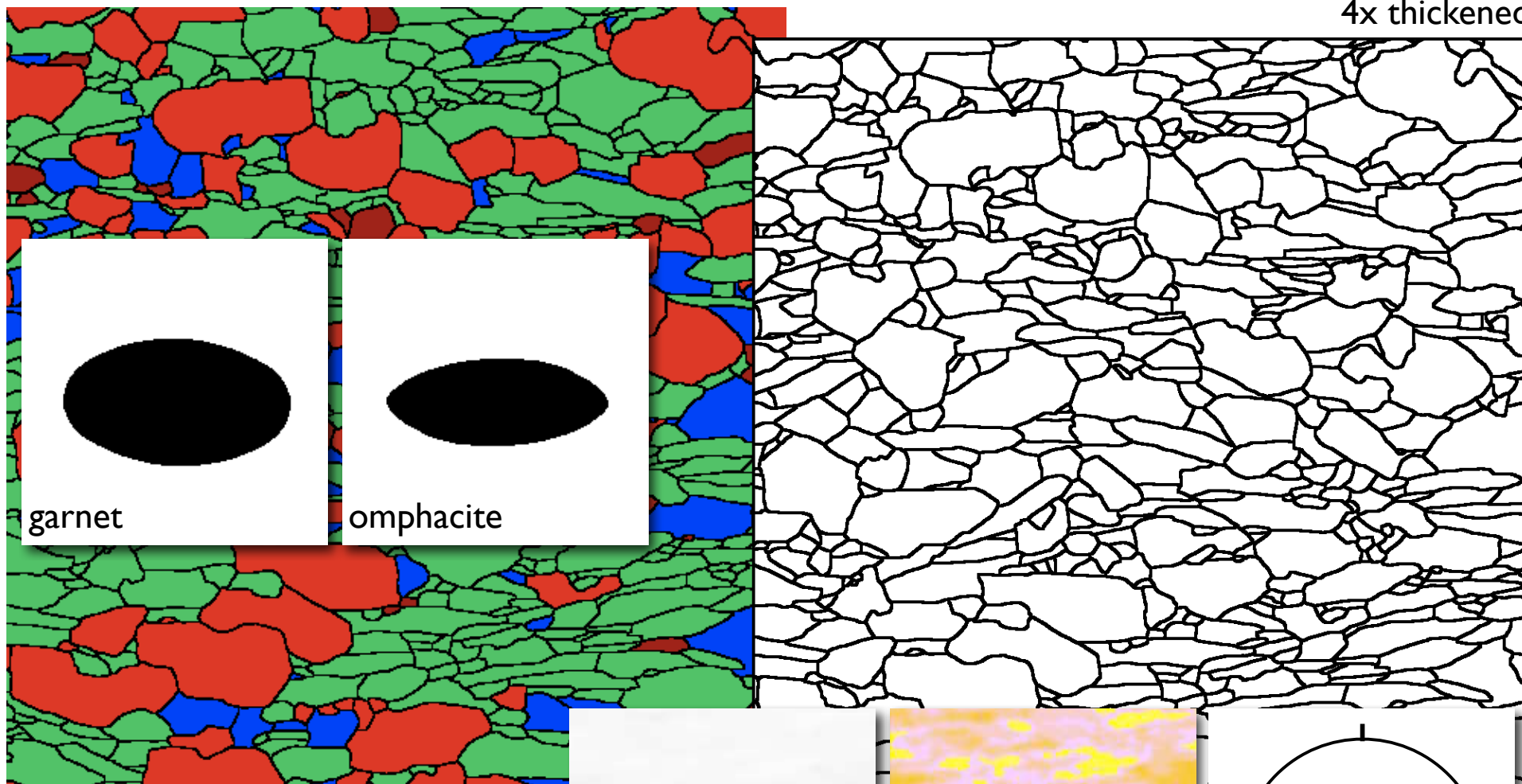


# ACF for surfaces

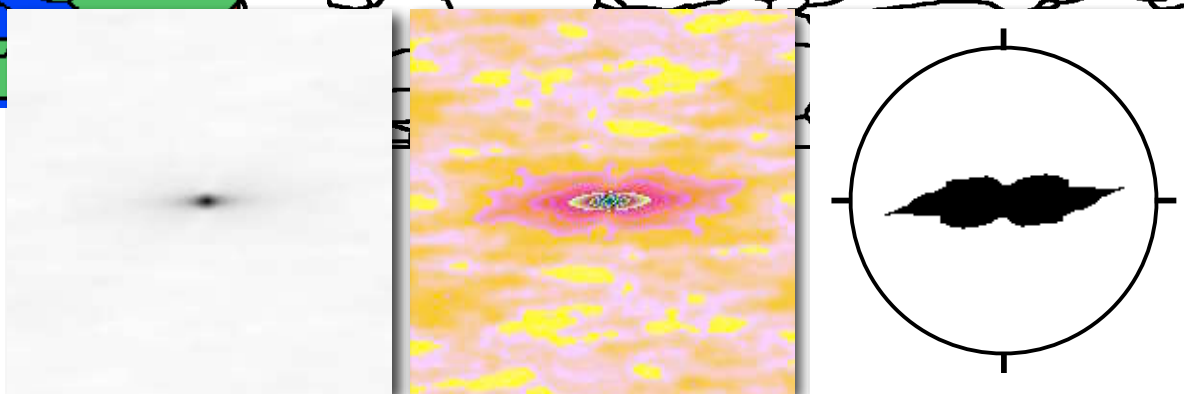


# ACF of grains and boundaries

4x thickened



central 200 · 200 of ACFs  
2x enlarged w/r to original



# Abschluss



# Image SXM

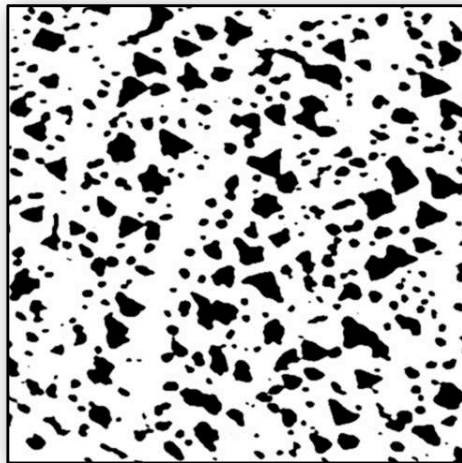


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<b>File</b> <a href="#">Edit</a> <a href="#">Options</a> <a href="#">Process</a> <a href="#">Analyze</a> <a href="#">Video</a> <a href="#">Macros</a> <a href="#">Stacks</a> <a href="#">SEM</a> <a href="#">SPM</a> <a href="#">Windows</a> <a href="#">Help</a>	<a href="#">New</a> <a href="#">Open</a> <a href="#">Browse</a> <a href="#">Import</a> <hr/> <a href="#">Close</a> <a href="#">Save</a> <a href="#">Save As</a> <a href="#">Export</a> <hr/> <a href="#">Record Preferences</a> <a href="#">Revert to Saved</a> <a href="#">Duplicate</a> <a href="#">Get Info</a> <hr/> <a href="#">Acquire</a> <a href="#">Export</a> <hr/> <a href="#">Page Setup</a> <a href="#">Print Image</a> or <a href="#">Print Text</a>	...
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# Zusatz: Re-direct

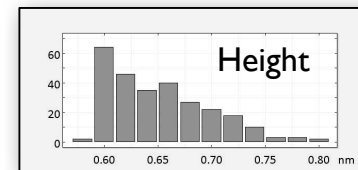
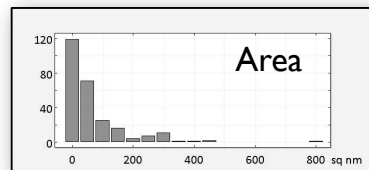
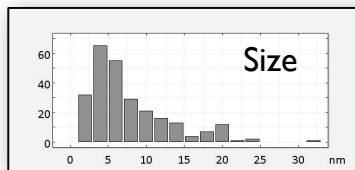
## Particle Analysis



	Area	Mean	StDv	X	Y	Len	Majr	Minr	Angle	Min	Max
1.	324.38	0.74	0.07	109.15	329.47	105.67	34.59	11.94	43.0	0.59	0.91
2.	6.86	0.63	0.02	135.40	341.15	11.54	4.65	1.88	9.0	0.59	0.65
3.	5.39	0.59	0.01	294.51	341.03	8.74	3.33	2.06	177.5	0.59	0.60
4.	4.90	0.61	0.02	340.76	339.57	12.36	5.79	1.08	94.9	0.59	0.65
5.	1.47	0.59	0.00	43.40	340.90	4.37	2.37	0.79	0.0	0.59	0.59
6.	10.29	0.62	0.03	129.07	339.20	11.13	4.40	2.98	172.8	0.59	0.67
7.	24.50	0.67	0.05	298.94	335.79	17.89	6.72	4.64	170.9	0.59	0.77
8.	5.88	0.65	0.04	172.26	336.17	8.74	3.63	2.06	175.2	0.59	0.70
9.	48.02	0.70	0.08	312.58	332.72	27.79	9.18	6.66	54.0	0.59	0.87
10.	40.67	0.64	0.03	28.80	332.96	24.07	8.05	6.43	5.1	0.59	0.68
11.	34.30	0.73	0.09	279.41	332.26	21.44	7.83	5.57	20.0	0.59	0.89
12.	6.37	0.61	0.01	252.92	333.85	9.73	4.17	1.95	13.0	0.59	0.63
13.	1.96	0.60	0.01	14.70	333.02	4.95	1.91	1.30	0.0	0.59	0.61
14.	5.39	0.63	0.03	264.09	331.23	8.33	3.33	2.06	2.5	0.59	0.67
15.	21.56	0.65	0.04	298.71	329.05	16.08	5.95	4.61	149.8	0.59	0.73
16.	5.39	0.60	0.01	233.04	329.57	8.33	3.49	1.97	13.3	0.59	0.62
17.	96.04	0.73	0.12	335.38	321.78	46.50	15.97	7.66	118.2	0.59	1.00
18.	44.59	0.65	0.03	223.54	326.75	24.82	9.36	6.06	175.6	0.59	0.70
19.	19.60	0.61	0.02	144.71	325.83	18.88	7.72	3.23	169.3	0.59	0.64



Mean nearest neighbour distance =  $13 \pm 5$  nm  
 Nearest neighbour lies in azimuthal direction  $83^\circ$  (anisotropy = 0.19)



After doing Particle Analysis, the option key changes 'Show Results' to 'Analyze Results', which generates the distribution histograms and displays (in the Info window and Results window) the NN distance, NN azimuth and anisotropy.

Anisotropy is calculated from the values of cos of twice the angle between a NN azimuth and a value of phi that varies between 0 and pi. The anisotropy is 0 if the NN azimuth of every particle is randomly distributed and 1 if the NN azimuth of every particle is the same.

# Image SXM help

After doing Particle Analysis, the option key changes 'Show Results' to 'Analyze Results', which generates the distribution histograms and displays (in the Info window and Results window) the NN distance, NN azimuth and anisotropy.

Anisotropy is calculated from the values of cos of twice the angle between a NN azimuth and a value of phi that varies between 0 and pi. The anisotropy is 0 if the NN azimuth of every particle is randomly distributed and 1 if the NN azimuth of every particle is the same.

# Themen

## 1. Grundlagen:

1. Bilddaten (VL1)
2. Arithmetische Operationen (VL2)
3. Skalieren Kalibrieren Verschneide-Operationen (VL3)
4. Re-sizing Pre-processing Segmentation Post-processing (VL4)
5. ACF (VL8)

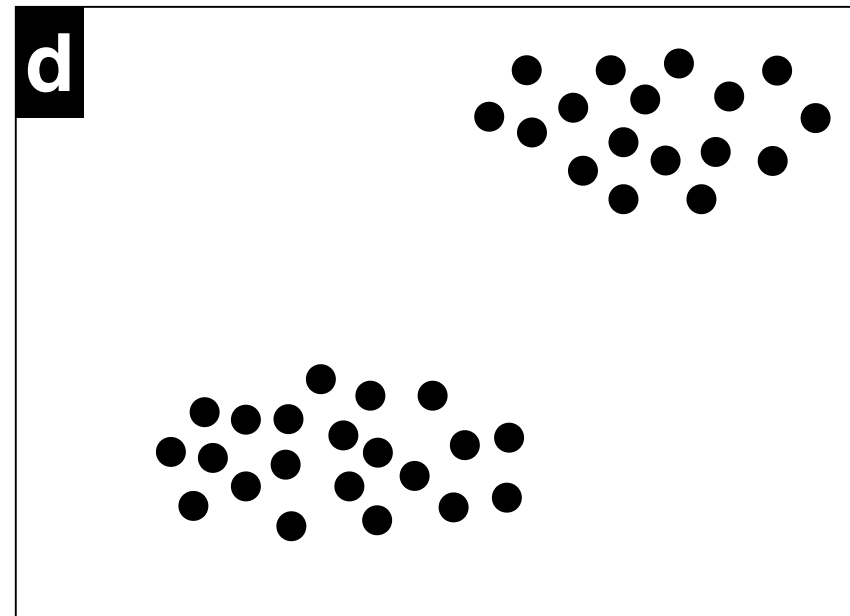
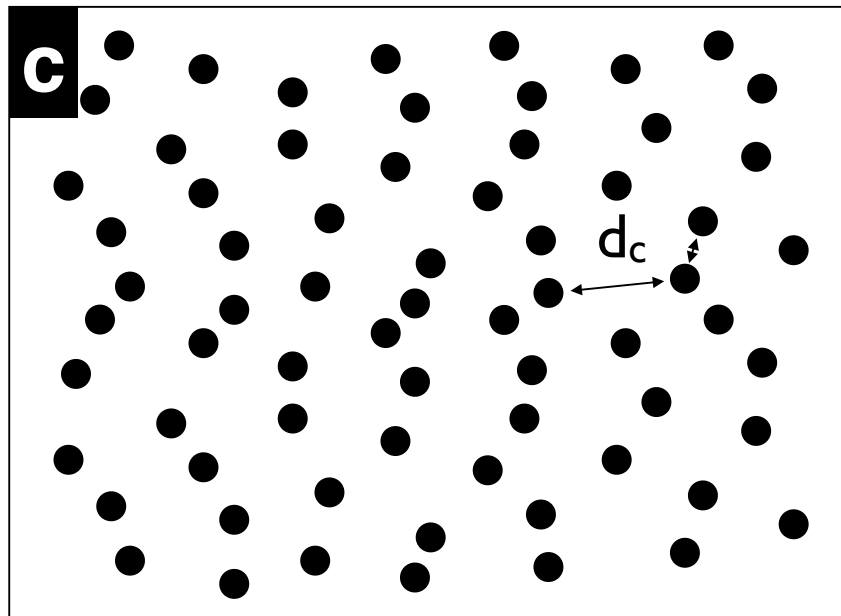
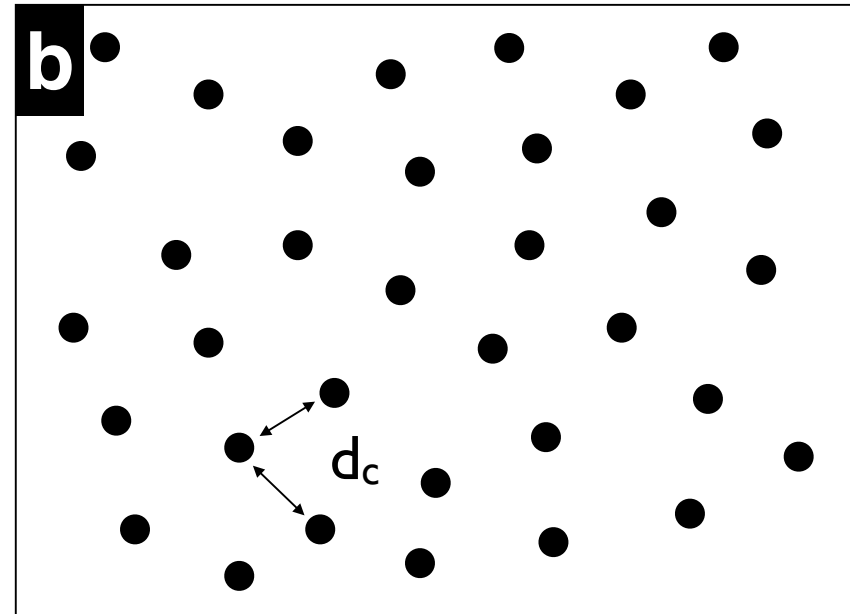
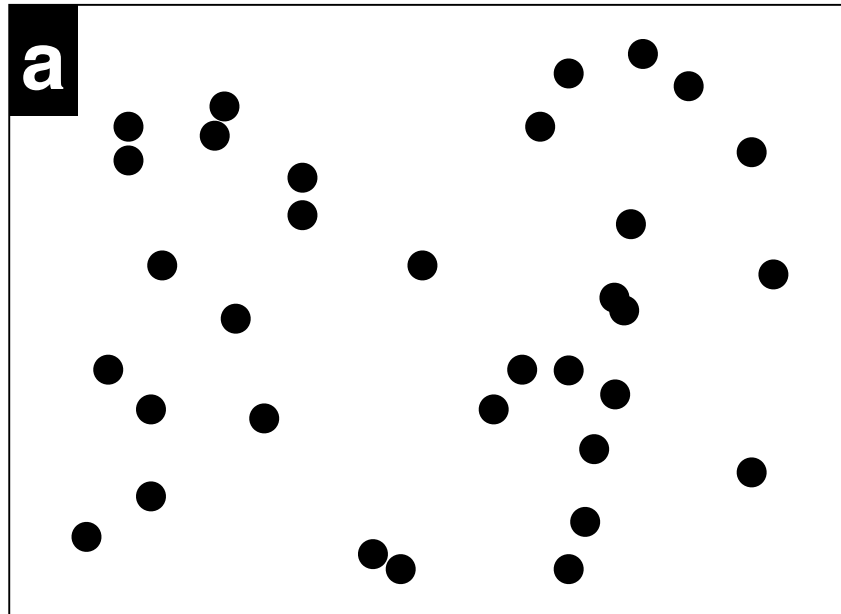
## 2. Anwendungen (s. Übungen):

1. Element- Phase- mapping
2. Geländemodelle
3. Volumbestimmung
4. Analyse: Korngrößen, Form und Einregelung
5. Visualisierung (property mapping)
6. Analyse:ACF

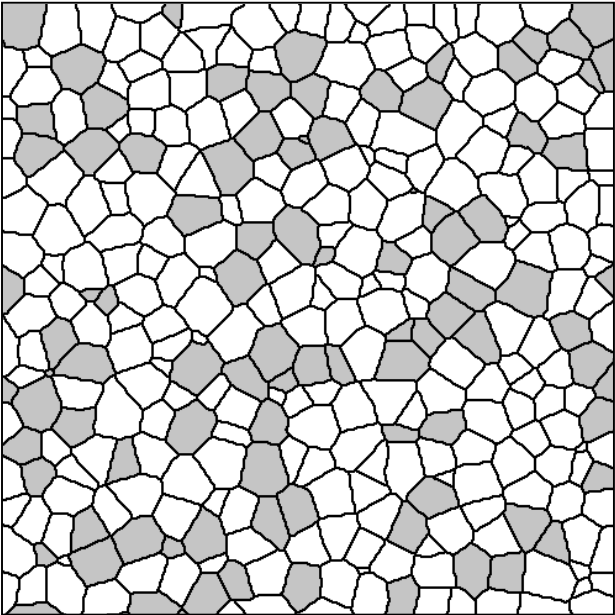
spatial  
distributions  
(für Hartnäckige)



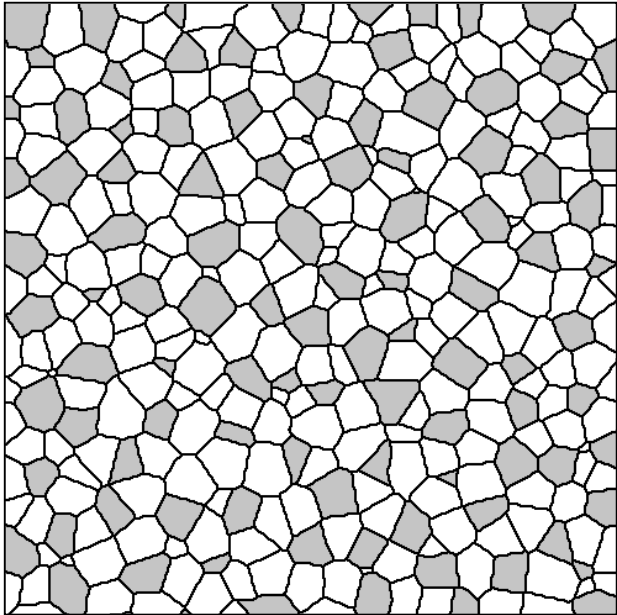
# Center point distribution



# Spatial distributions of phases

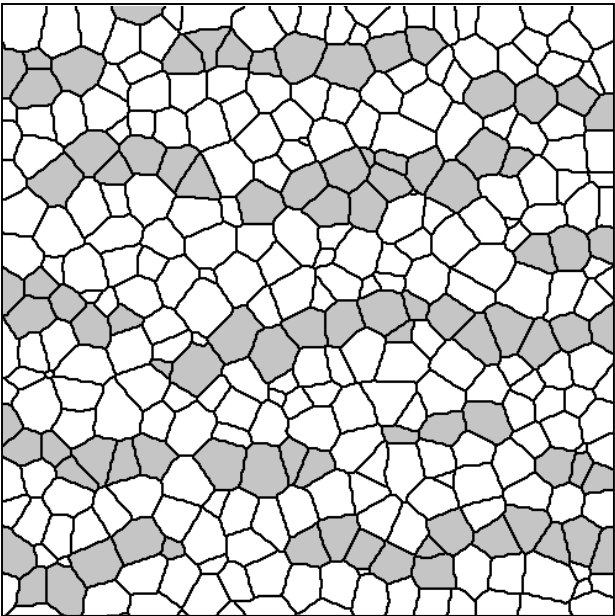


random

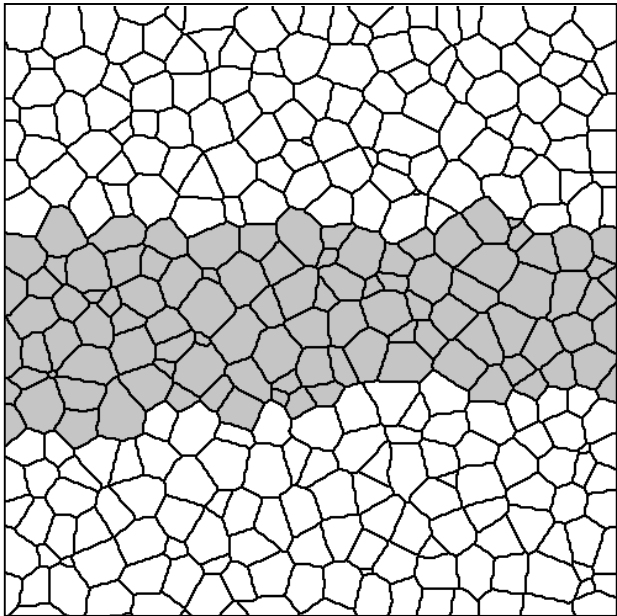


ordered

■ A  
□ B

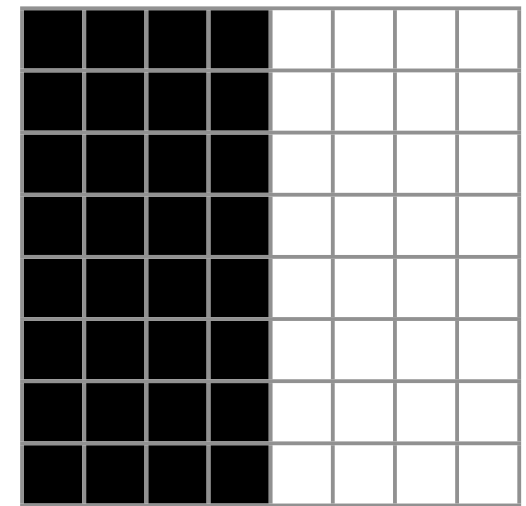
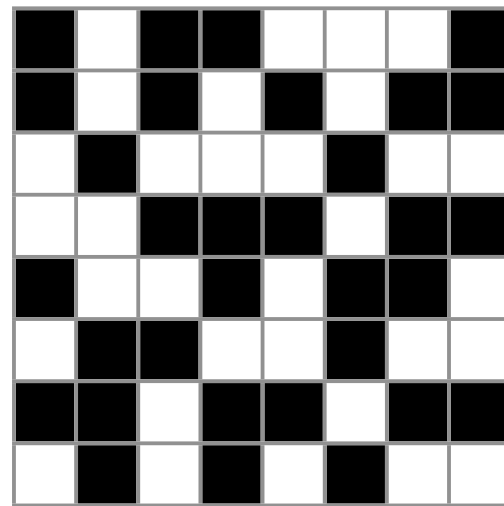
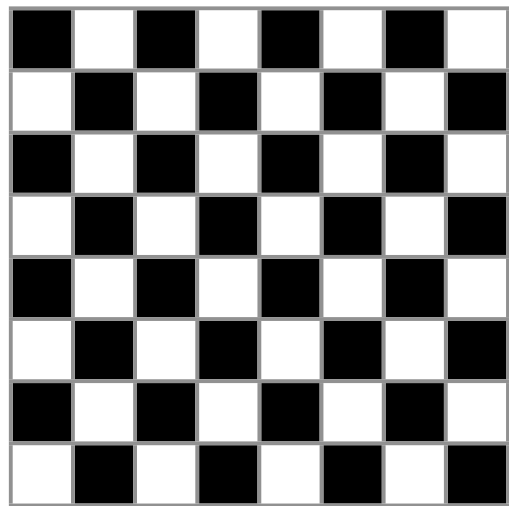
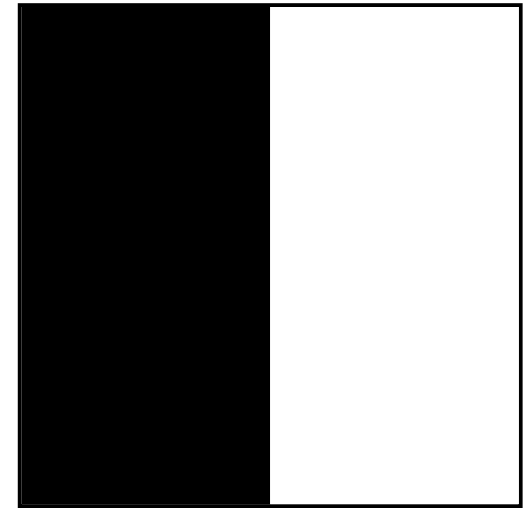
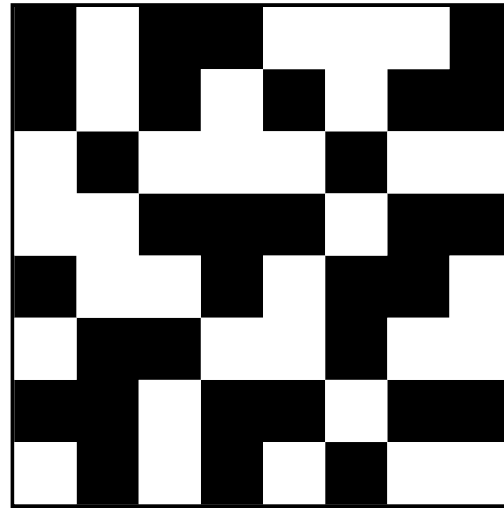
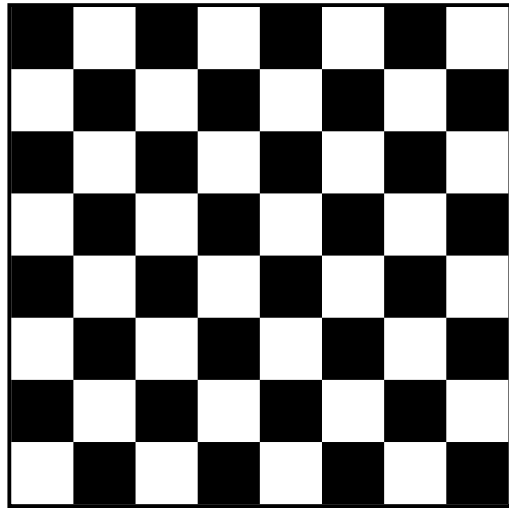


clustered



highly  
clustered

# ordering

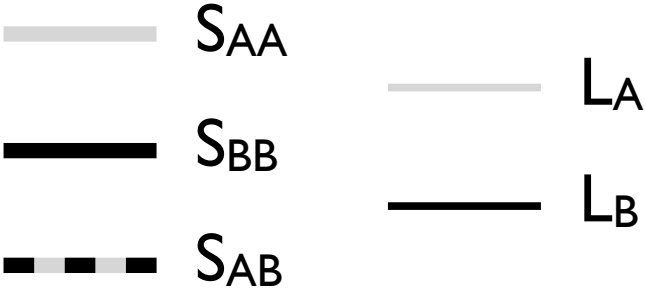
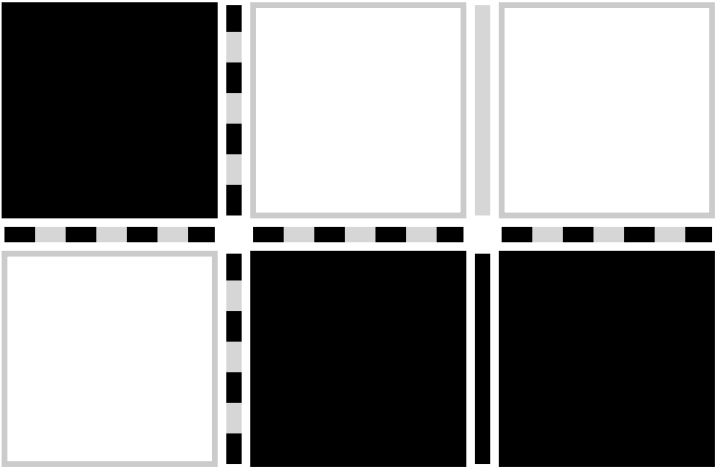
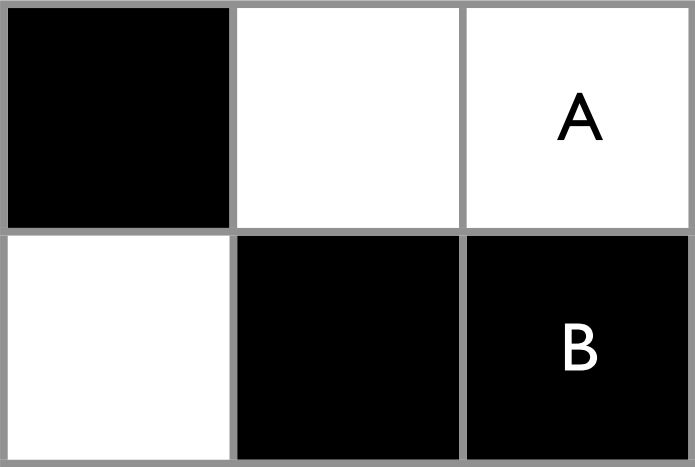


ordered  
(anti-clustered)

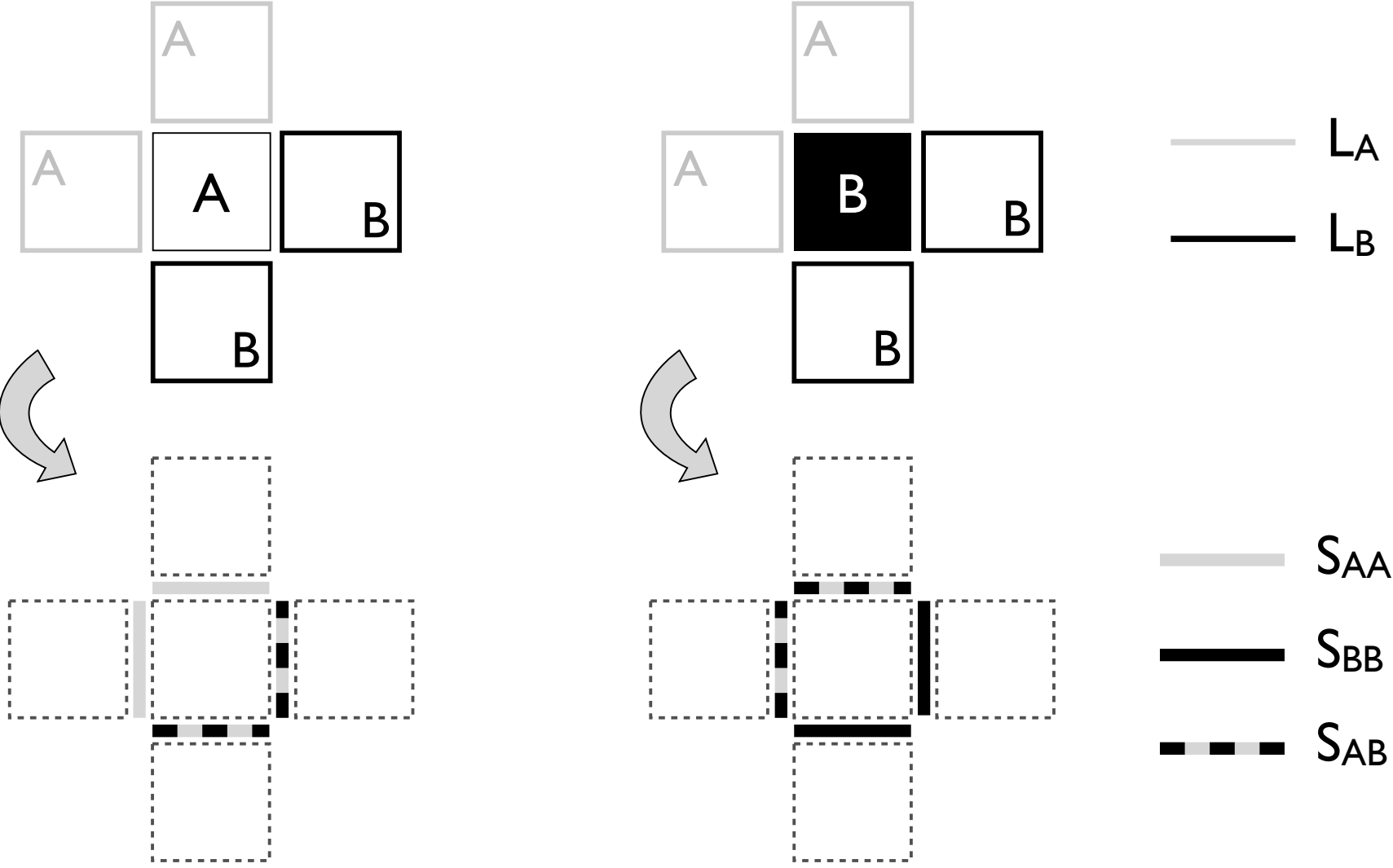
random

clustered

# contact surface model

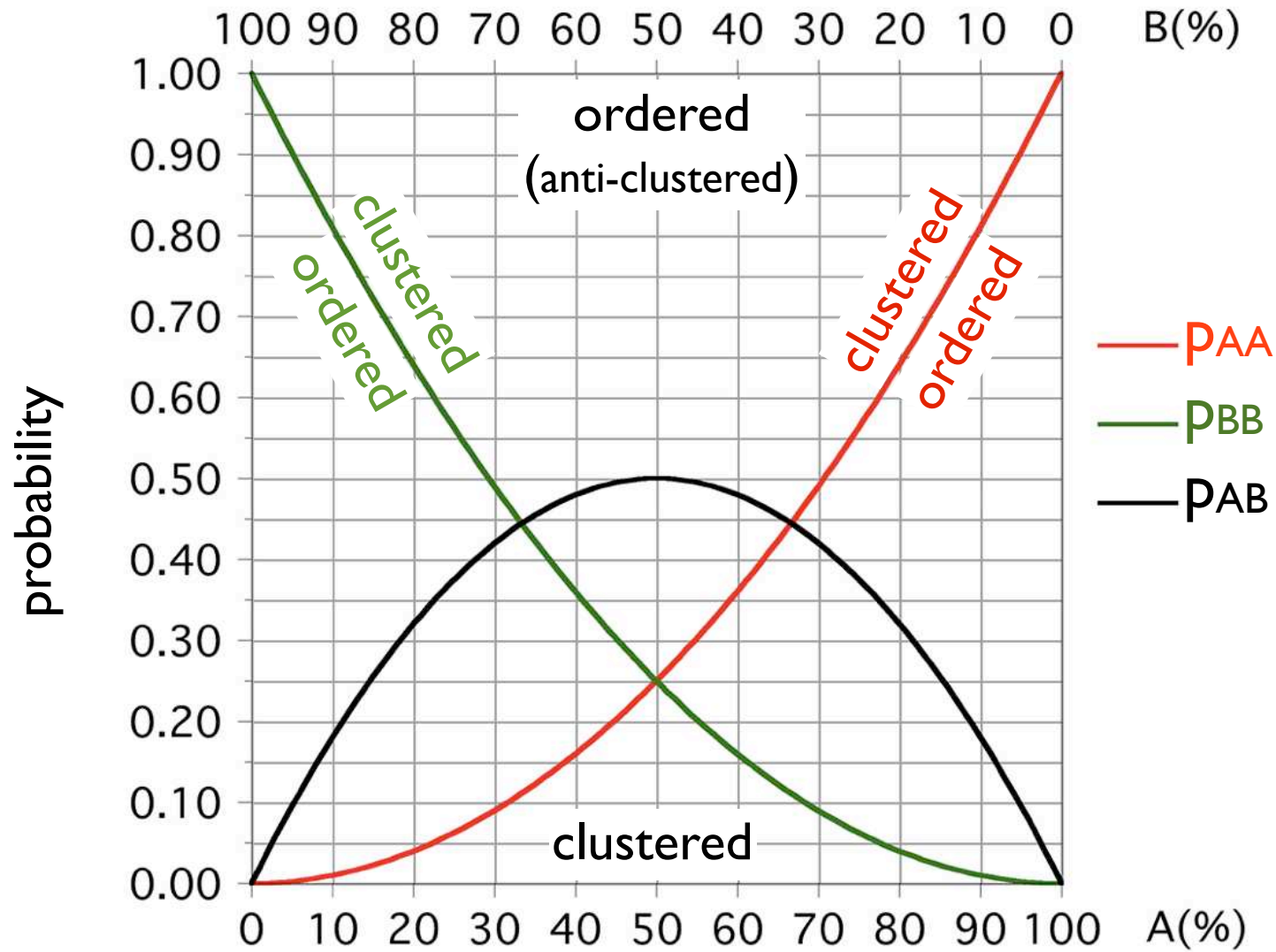


# contact probabilities

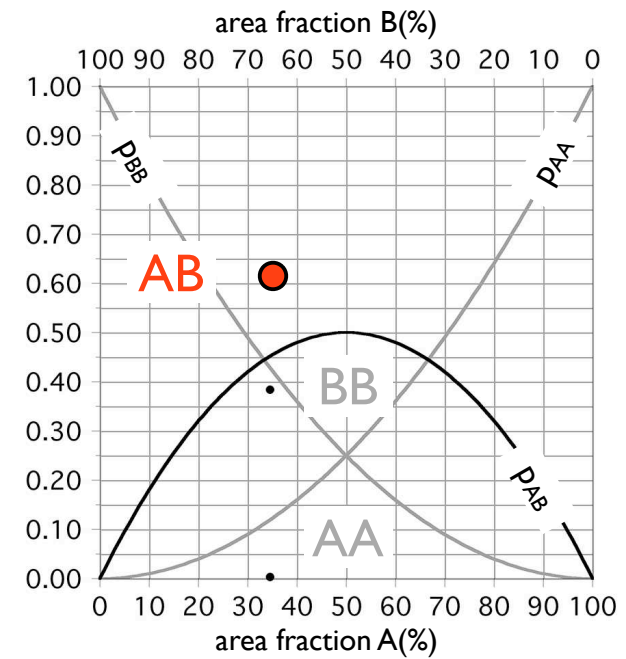
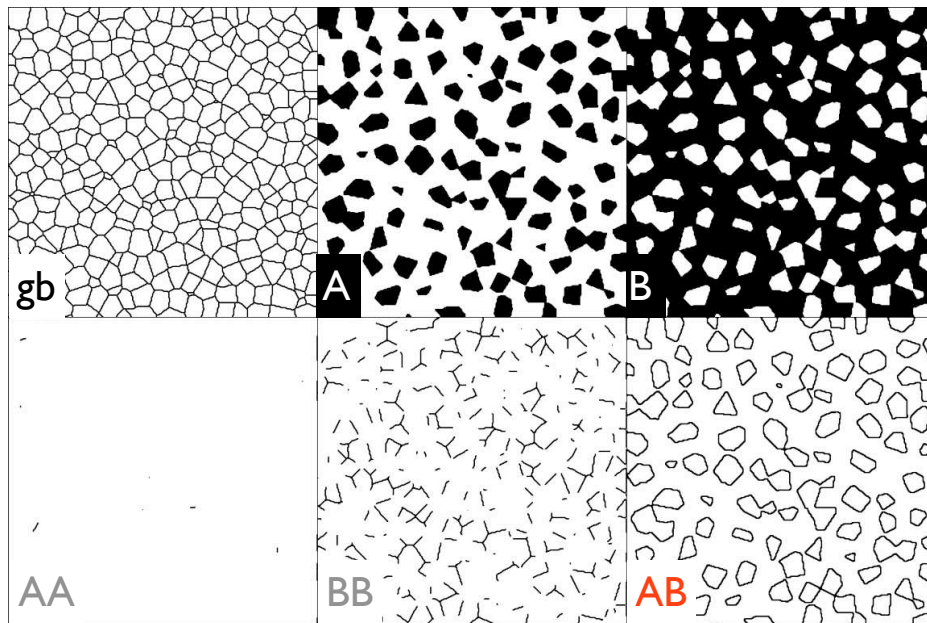
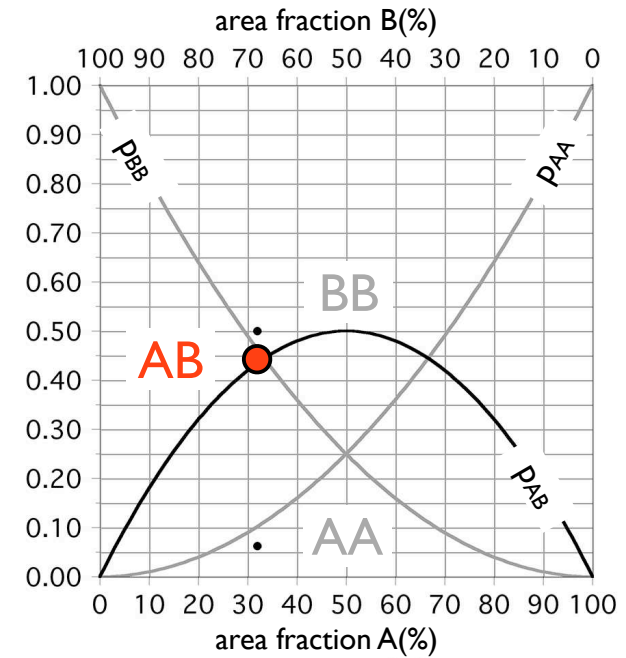
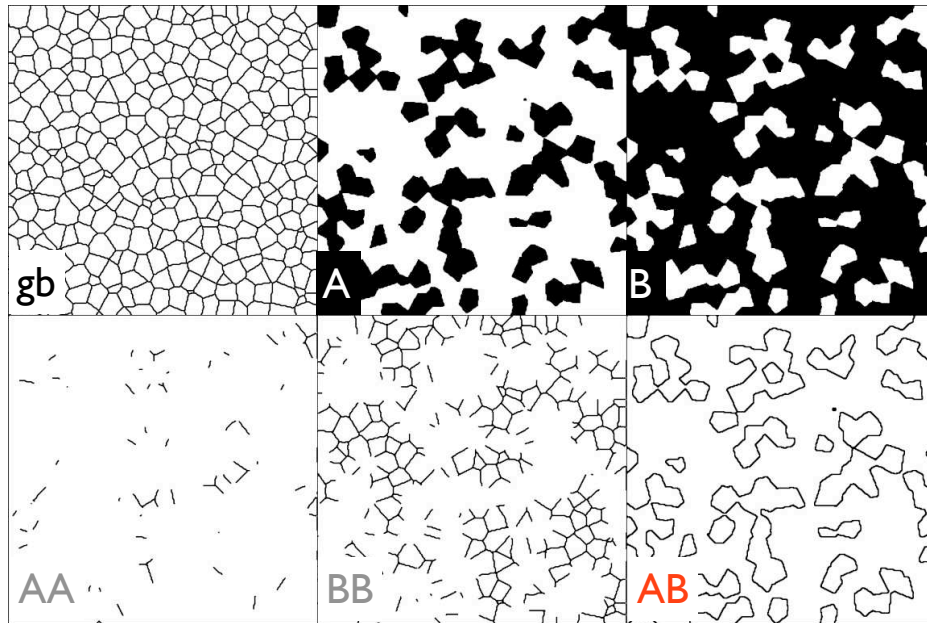




# binomial



# random - ordered



# clustered - segregated

