Shape Preferred Orientation (OCW-UN-SPO) Launeau P. 2017

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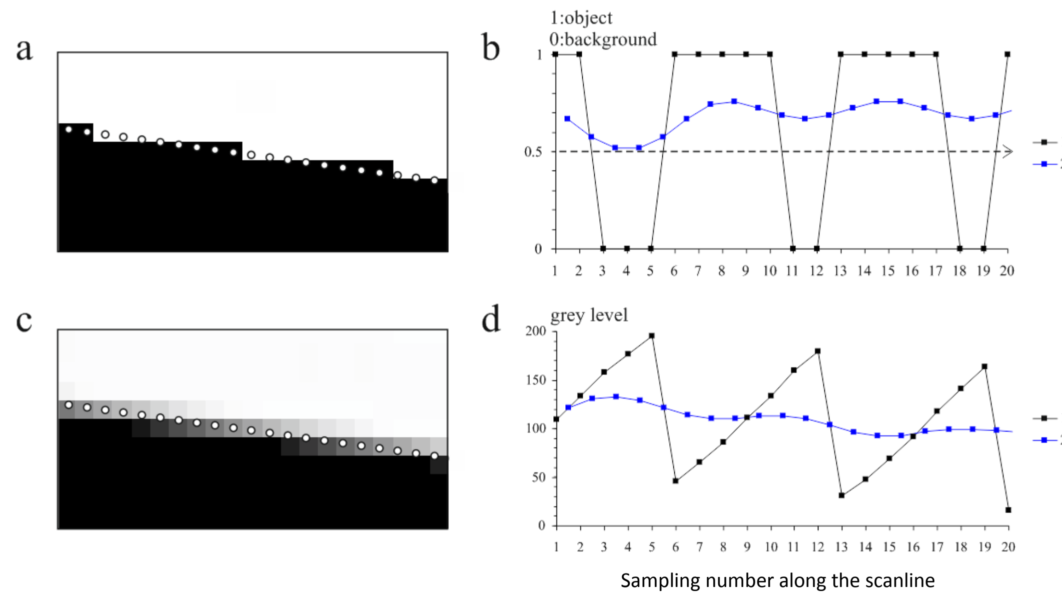
A classified image is typically a binary image (a) with a mineral class in black (value 0) on a white (value 1) background. In case of multiple (n) classes it is a stack of n binary maps or one image with n color codes or n class numbers representing the classes from 1 to n with 0 being the class number of unclassified pixels.

In grey level images (c) there is no classification and each pixel has a value ranging from 0 to 255 in case of 1 byte or 8 bits eventually colored in false color with a palette.

The resampling of each image by a grid of analysis may tangent an object boundary. (b) Is a profile of the binary image (a) coded in real for pixel density calculation. (d) Is the profile of the grey level image (c) also coded in real for density pixel calculation.

1 – resampling along any line direction in grey level

2 – smoothing sampled line with [1 3 6 8 9 9 8 6 3 1] / 54

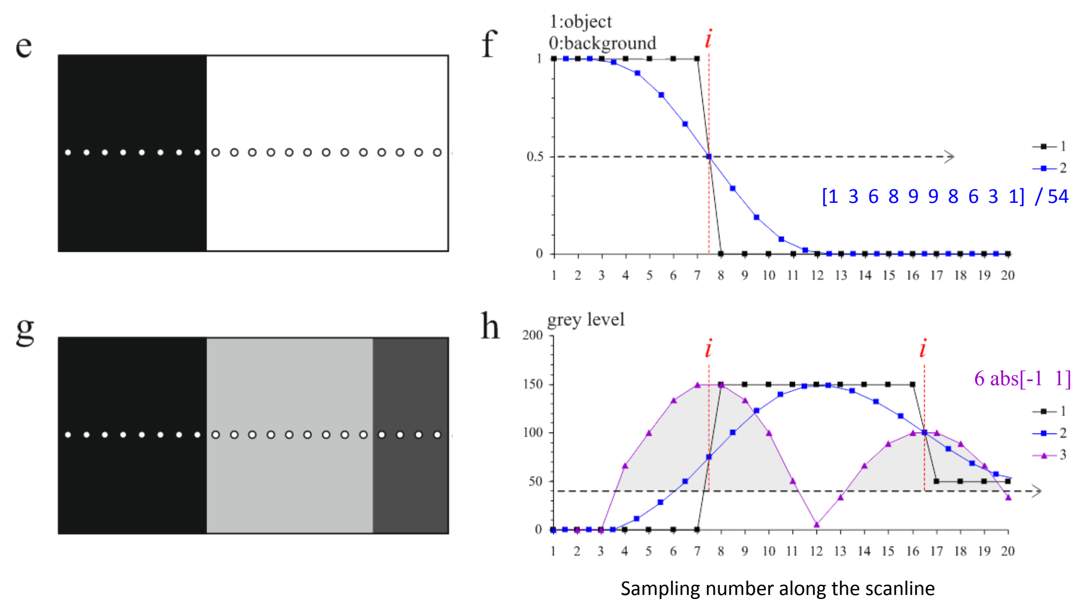


The grey level image display smoother boundaries because of the intermediate grey values (c) which cannot exist in binary images (a). The low-pass filter is therefore more efficient in grey level images.

Launeau *et al.* (2010) see also Lebichot *et al.* (2005)

The pixel density of binary classified image gives values ranging from 0% to 100% and a boundary can be found when leaving an object along a scan line at each sampling cursor passing below 50%. In a greyscale image the boundary between 2 objects is a local sharp transition of grey levels which can be anywhere between 0 and 255. So there is not unique level of detection and it becomes necessary to define an image of boundary detection.

Boundary detection are commonly done in image analysis by high-pass filter detecting the boundaries between multiple grey levels. Because of the very long low-pass filter use to smooth the detection of intercepts a very short high-pass [-1, 1] filter can map (h) the grey level transition between neighboring pixels along the scan line .



The absolute value of [-1, 1] times 6 allows the detection of boundaries, from both dark to clear and clear to dark grey level sampled pixels, with intensities equal to the grey level contrasts between objects (each maximum of plot 3 is equal to the contrast between objects of plot 1)

Launeau *et al* (2010) see also Lebichot *et al* (2005)

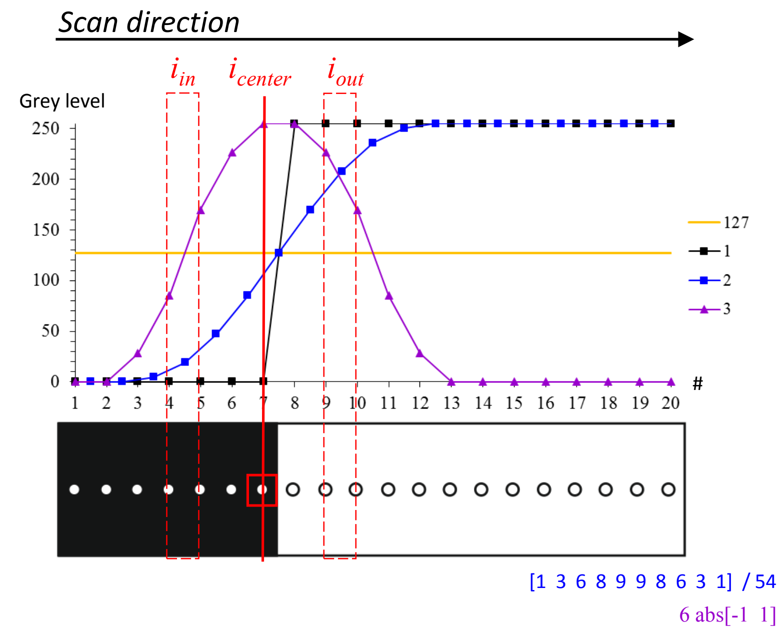
The new procedure of intercepts detection is applicable to binary images by setting the class object number 1 to the grey level 0 and the class background number 0 to 255 (plot 1) with a 50% detection level at 127 (orange plot).

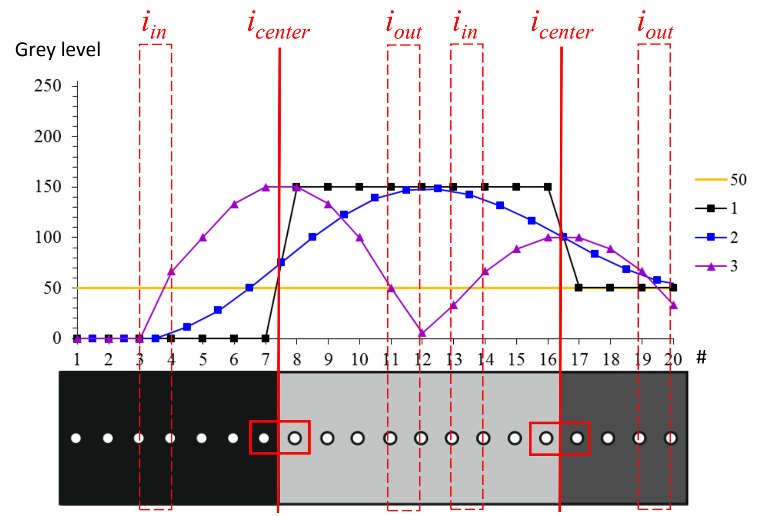
(1) Is the plot of the grey level image sampling.
(2) Is the low-pass filter necessary to smooth out the over counting of tangent scanlines.
(3) Is the high-pass filter scaled to the grey level contrast between objects facilitating the choice of intercept detection threshold. Each boundary between objects appears as a bell curve centered on one intercept.

The new procedure scans plot 3 detecting bell curves in and out intersections with the intercept threshold level of detection (orange). Then, each intercept twin “in and out” is replaced by a unique centered intercept i_{center}.

In the grey level example the contrast of intercepts detection set to 50 detects 2 intercepts. A threshold at 100 would detect only 1 intercept.

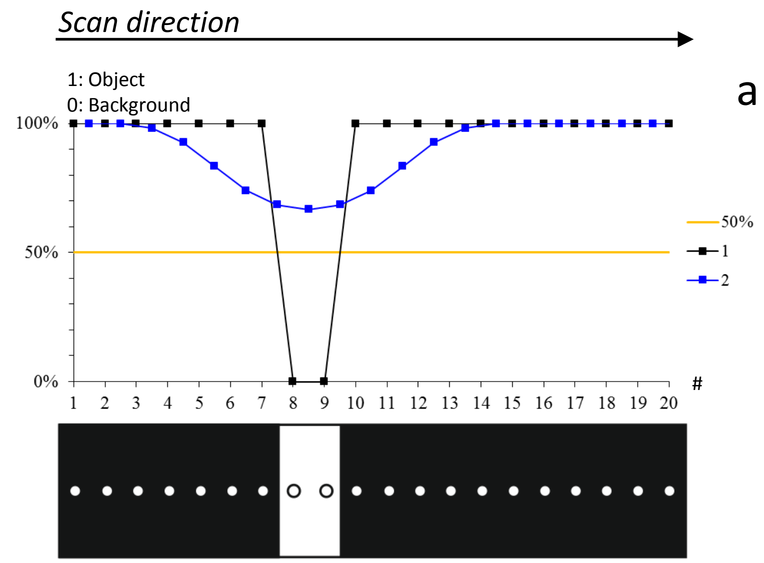
Launeau *et al* (2010)



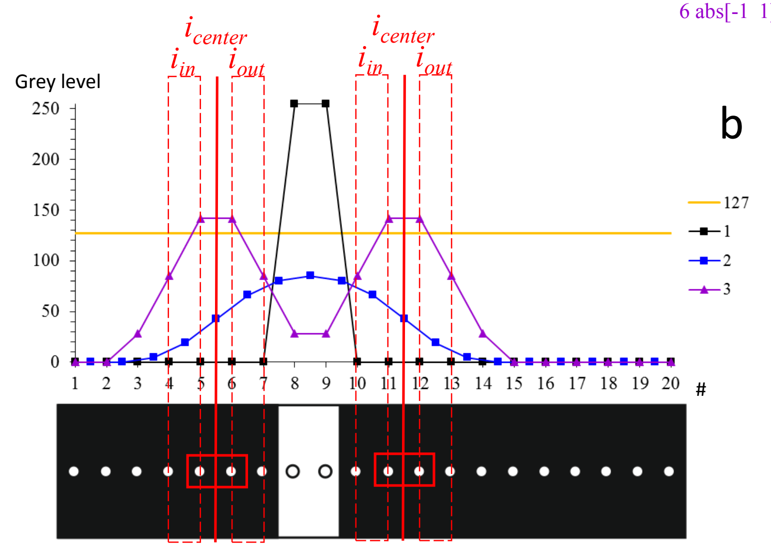


In case of borders found between 2 pixels only one of them is recorded in memory.

The intercepts method counts intercepts each time a scanline cursor get out of the mineral class. The old application of this method to classified digital images counts one intercepts on a weighted pixel densities along scanline each time this pixel density goes below 50%. Because of the 10 pixels long smoothing filter a minimum thickness of 4 pixels is required between 2 objects. Shorter distances are not detected like in figure a.



The new 2 step procedure of intercepts counting in grey level allows the analysis of narrower lines. Figure b displays an example with a grey level contrast set at 127 which corresponds to 50% of the maximum grey level at 255. The same threshold level at 50% is therefore more efficient in grey level than in classified image procedure.

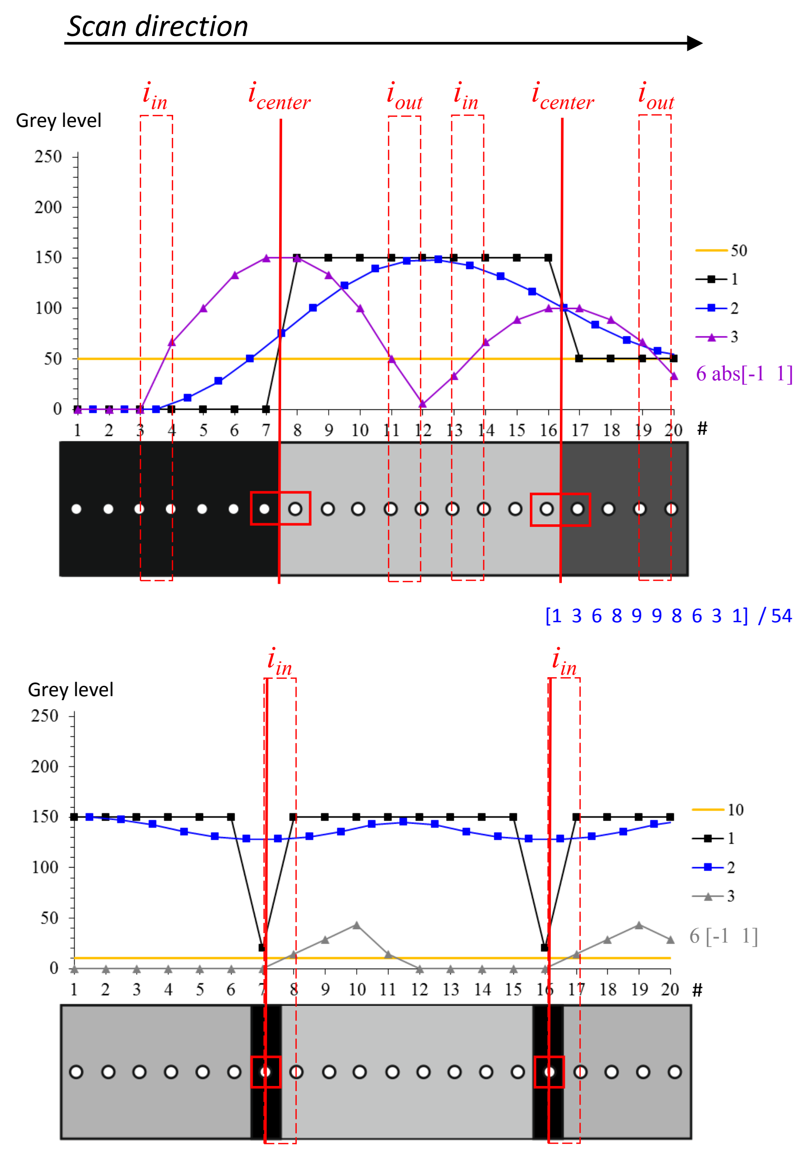


In case of borders found between 2 pixels only one of them is recorded in memory.

Launeau *et al* (2010)

The new procedure of intercepts counting in grey level also postulates that each object is a patch of pixels with homogeneous grey level in contact with each other. Therefore a boundary of grey level objects has no thickness and may be localized in the first pixel in or out of each object.

In case of dark boundaries of grey crystals in metallographic images or in case of dark faults distributed on a lighter background it is necessary to consider each dark boundary as a line with no thickness by counting only 1 intercept per line. This can be done by retaining only the positive values of high-pass filter [-1, 1] and using a low threshold of grey level contrast for the counting procedure.



Launeau *et al* (2010)

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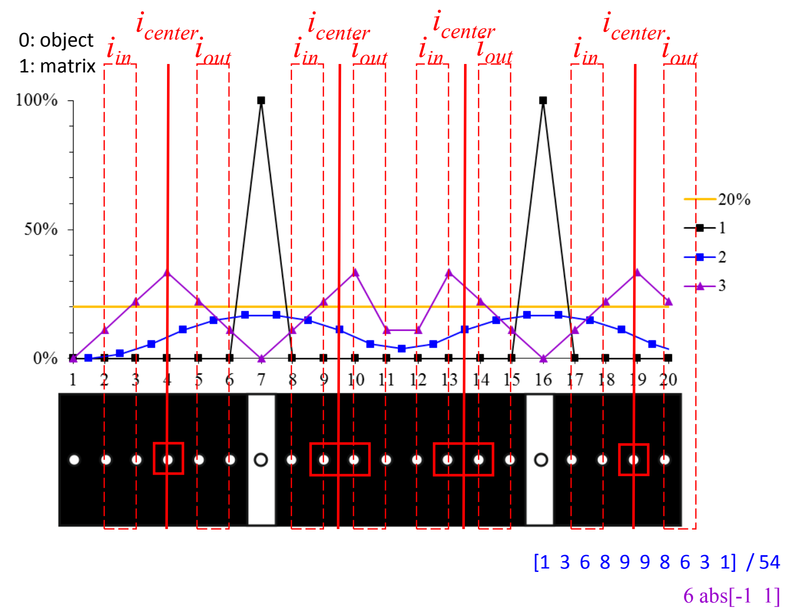
The new procedure of intercepts detection is applicable to classified images by processing each class on a distinct image layer setting any class number to the level 0 (coding black objects) and all other class to 100 (coding white embedding matrix) with a threshold of contrast which can vary from 0 to 100% with a default value at 50%.

More over, when objects have been labelled with a specific code number during an inertia tensor calculation for example, each object can ne processed individually.

To summarize, intercepts are counted twice when objects are bounded by thick lines delineating the boundaries and only once when objects are directly in contact with borders without thickness.



Launeau *et al* (2010)

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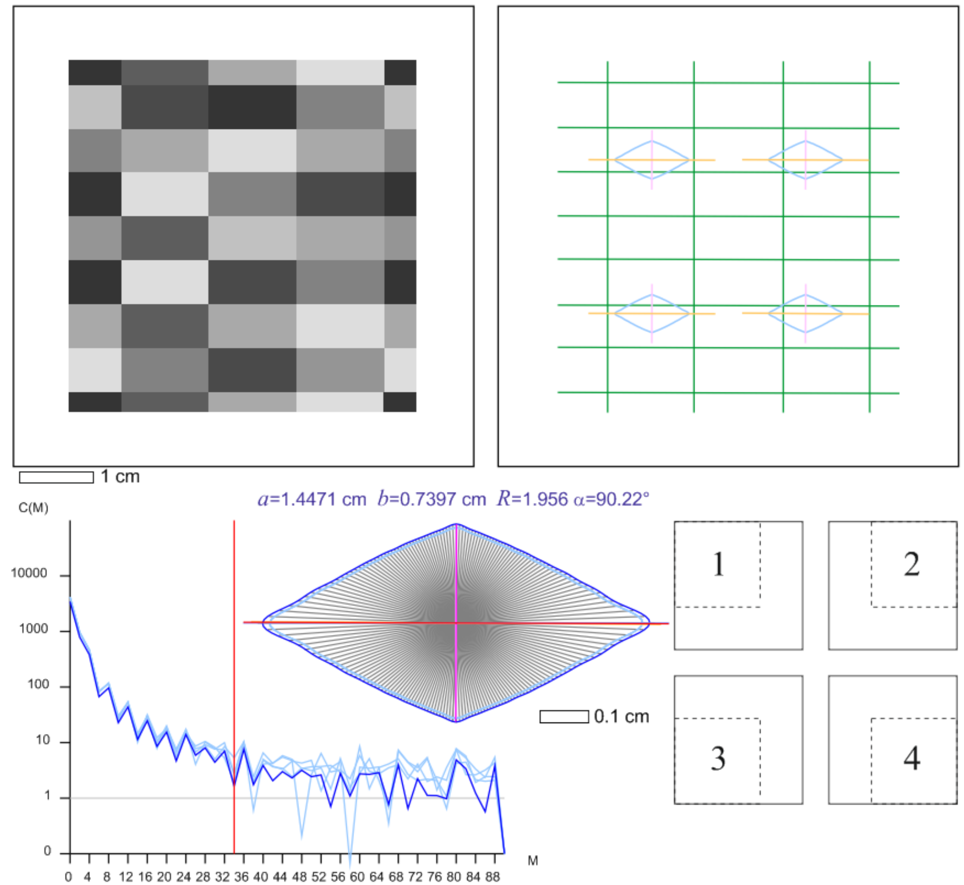
The measurement mask, set to a quarter of the image, scan from position 1 to 4 over it allows a quantification of the results invariance by translation. It gives 4 SPO whose R and α standard deviations characterize the results homogeneity through the whole image.

More over, since fragments of rocks may cut grains and display a large margin around them, a mask must be defined to stop the detection of intercepts along the fragment boundaries. For instance the grains have different grey levels and the empty space around the fragment is white in the present example.

The intercepts method in grey level can works on fragmented grain while their fracture are not counted as intercepts. Then, this simulation of synthetic rectangles with r=2 parallel to each other displays the expected SPO.

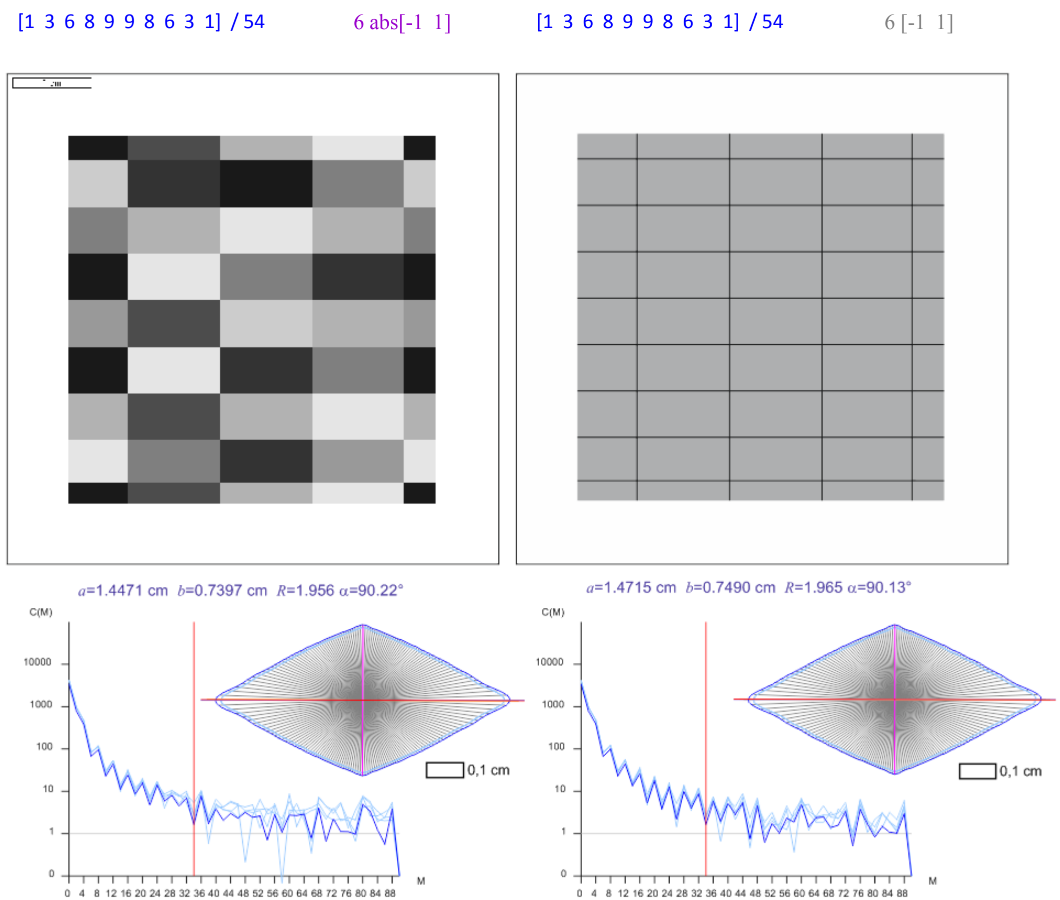


Launeau *et al* (2010)

This simulation of synthetic rectangles with r=2 parallel to each other displays the expected SPO R=2 α=90°.

In the standard grey level image the boundaries have no thickness and they are all detected with the procedure using the absolute value of the high-pass filter.

In the grey image with dark borders boundaries have a thickness and could be counted twice. The positive value selection of the high-pass filter allows to count intercepts once per boundary which gives the expected results.

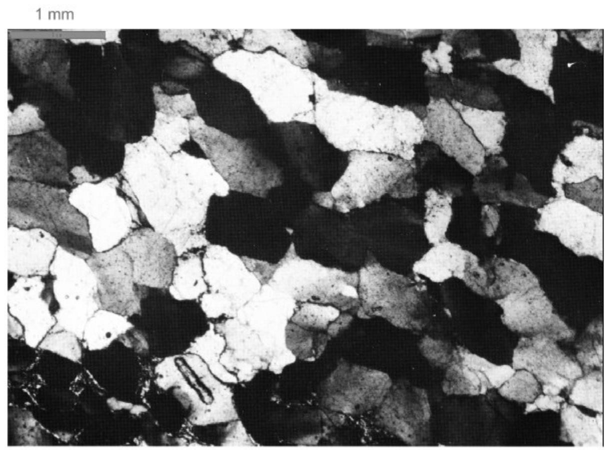


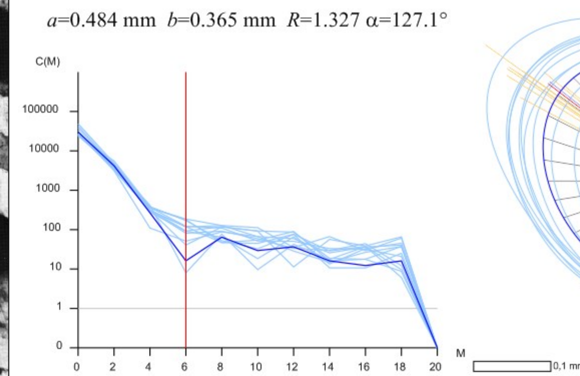
Launeau *et al* (2010)

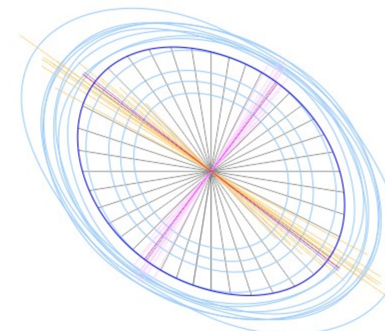
The measurement mask can divide an image having a 4/3 elongation area in 4×3 square sub-windows giving 12 SPO which characterize the homogeneity of results through the whole image of this example. The results are close to those presented in course 4 p. 37 & 38

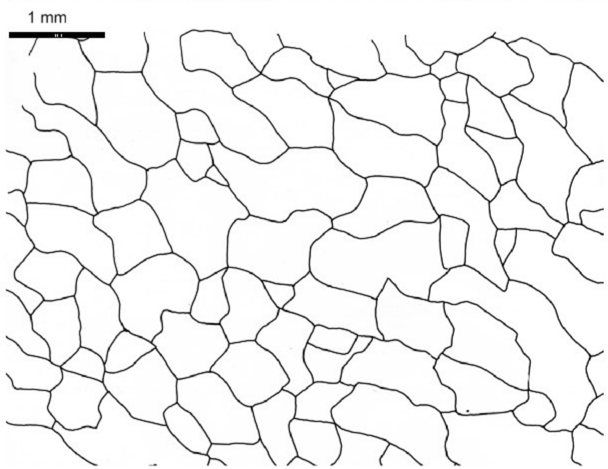
Classified drawing image
Inertia/A
R = 1.32
α = 125.0
Inertia
R = 1.43
α = 123.7
Intercepts without cutting
R = 1.37
α = 124.5
Intercepts
R = 1.30
α = 125.4

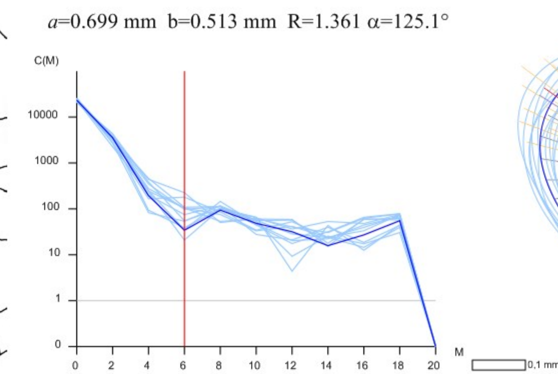
Greyscale image
Intercepts of the picture
R = 1.33
α = 127.1
Intercepts of the drawing
R = 1.36
α = 125.4

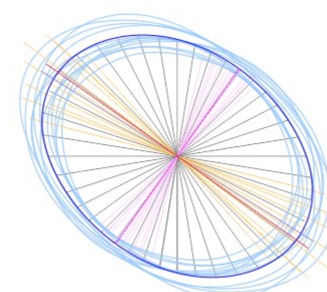












Picture and drawing scanned from a quartzite thin section modified from Ramsay and Huber (1983, page 118).

Launeau *et al* (2010)

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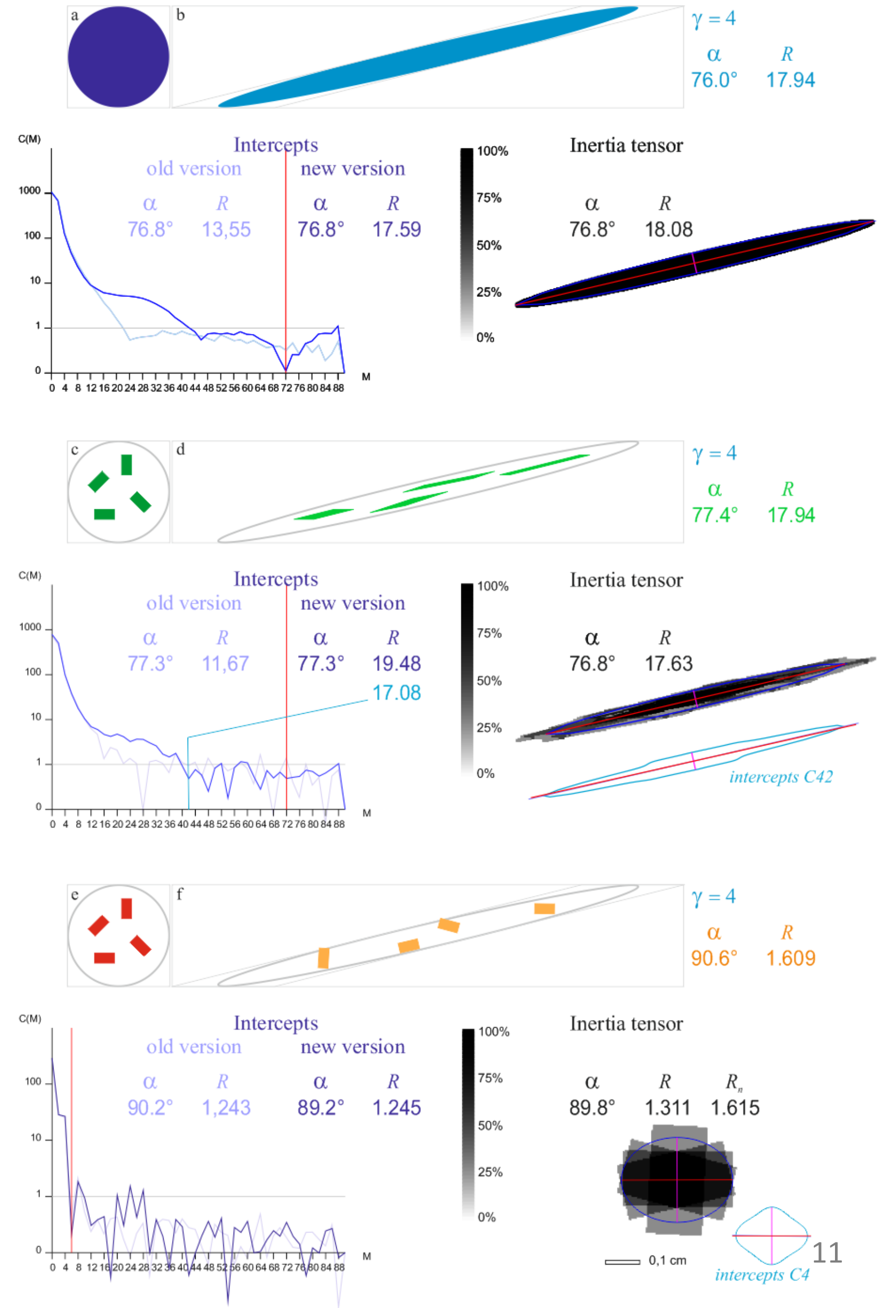
This set of simulations symbolizes the **passive deformation** of an enclave from a to b, the passive (solid stat) deformation of 4 microliths from c to d and an **active** (magmatic) **deformation** by rigid body rotation of the microliths from c to f.
The old intercepts method cuts the high frequencies which makes difficult the detection of sharp ellipse ends. The new method allowing the detection of narrow shapes better estimates sharp ellipses.
In both cases of passive deformation both new intercepts and inertia tensor method can retrieve the expected values.
In case of active deformation the inertia tensor allows the calculation of the mean shape ratio of each object allowing also the calculation of R_n. The inertia tensor method gives the best results and there is no difference between intercepts procedures for weak anisotropies.

Launeau *et al* (2010)



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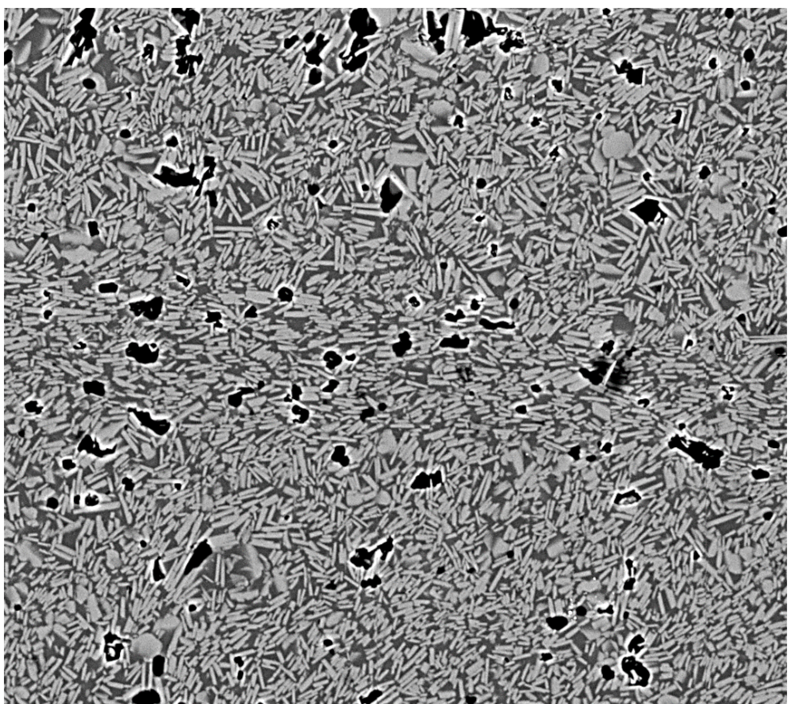
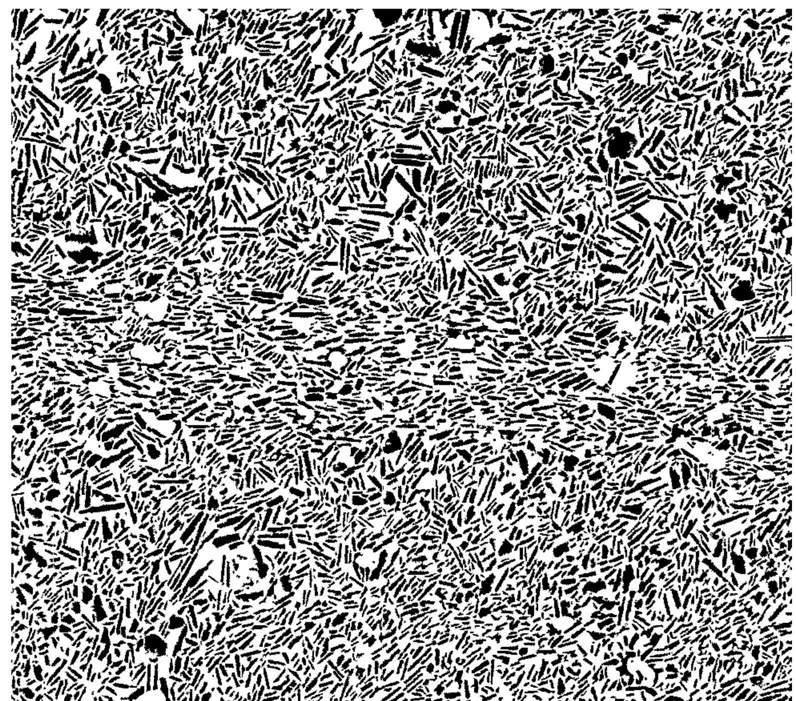
The main interest of the grey level intercepts method is its fast processing. Image classification, even by a simple threshold in grey level, necessitates a lot of time, especially when crystals in contact with each other required manual segmentations. This is the case of the example below for which the operator had to draw many boundaries between aggregated crystals prior the application of the inertia tensor method whereas the intercepts method in grey level automatically detect the orientation of crystals despite their aggregation.

Plagioclase-bearing suspension composed of 52% of crystals was synthesized and then deformed using a Paterson HP-HT apparatus at a confining pressure of 300 MPa, a temperature of 850°C and a shear strain γ = 3.5



Launeau *et al* (2010), Picard *et al.* (2013)

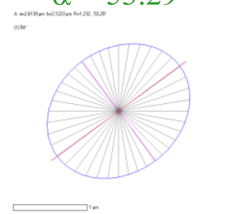


D. Picard at al 2011, Geology, doi 10.1130/G32217.1

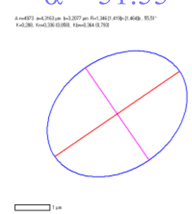
But, if a few crystals are in contact some boundaries are missing. So, let compare SPO of intercepts counting in grey level with SPO of classified image inertia tensor to check the impact of the missing boundaries.

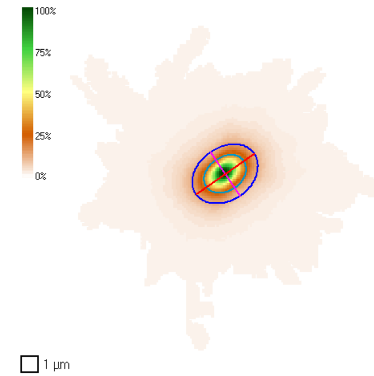
As already shown in course 4 (p.27) intercepts underestimate the SPO intensity. Moreover, the inertia tensor allows the calculation of mean crystal r and normalized SPO R_n. A shear band of flow concentration also better appears with the orientation color code of individual crystals.

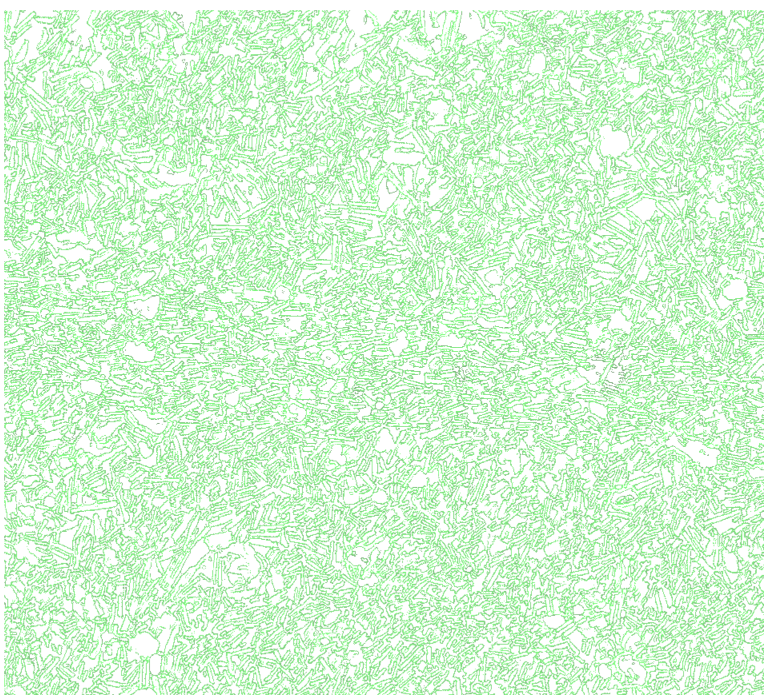
SPO intercepts
$R = 1.232$
$\alpha = 53.29$

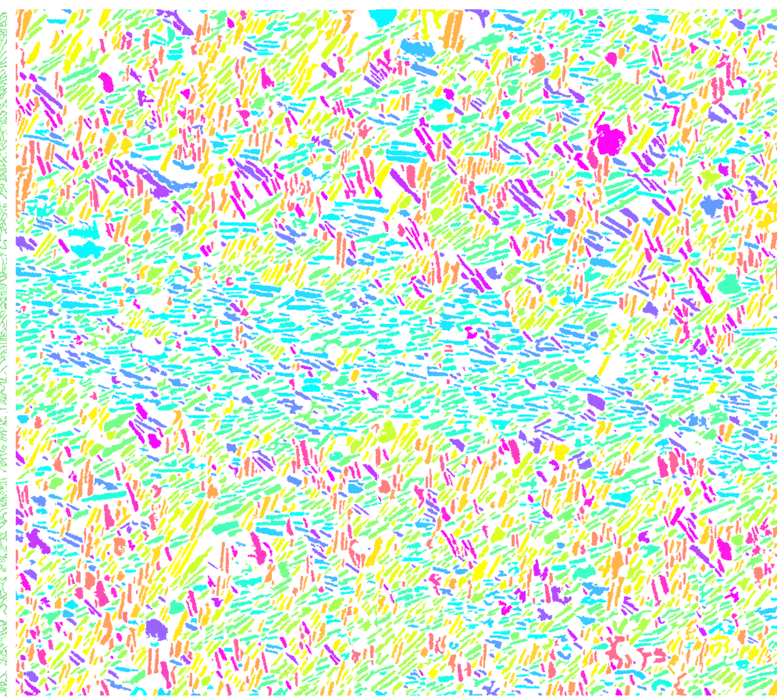


SPO inertia
$R_n = 1.419$
$R = 1.346$
$\alpha = 51.55$









Shear band

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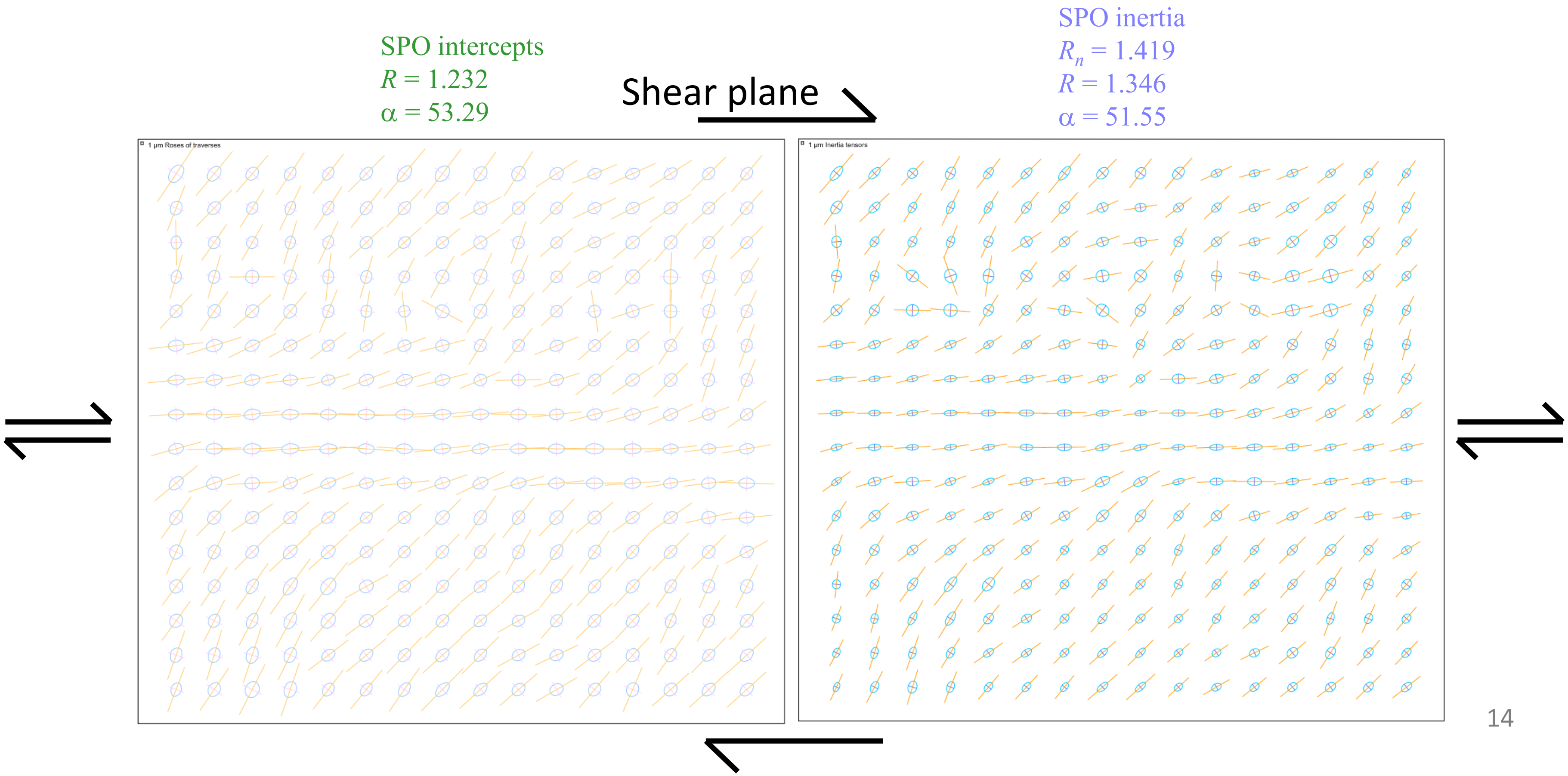
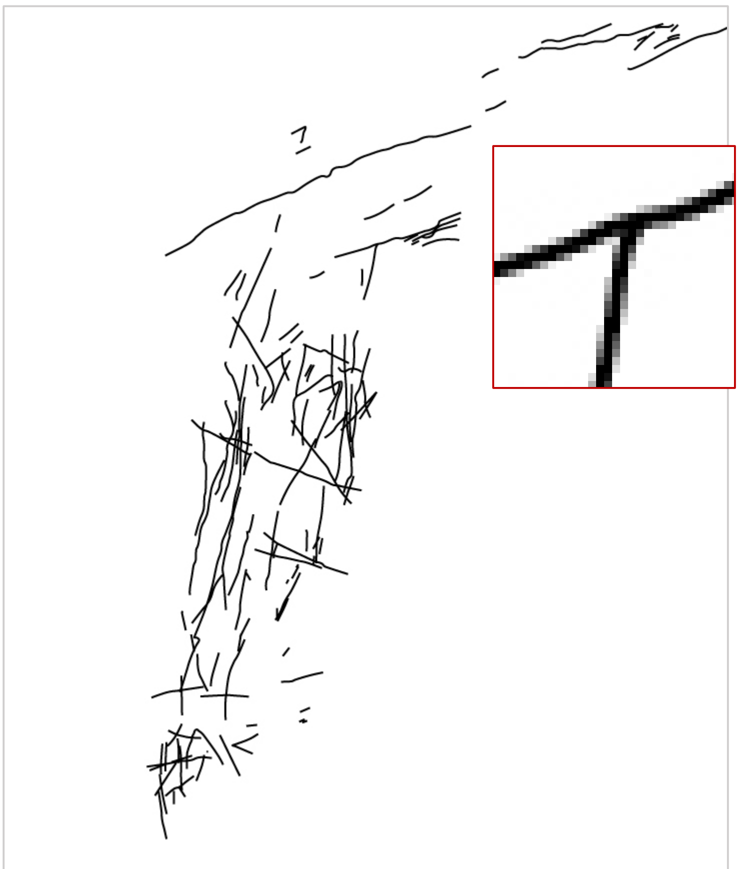
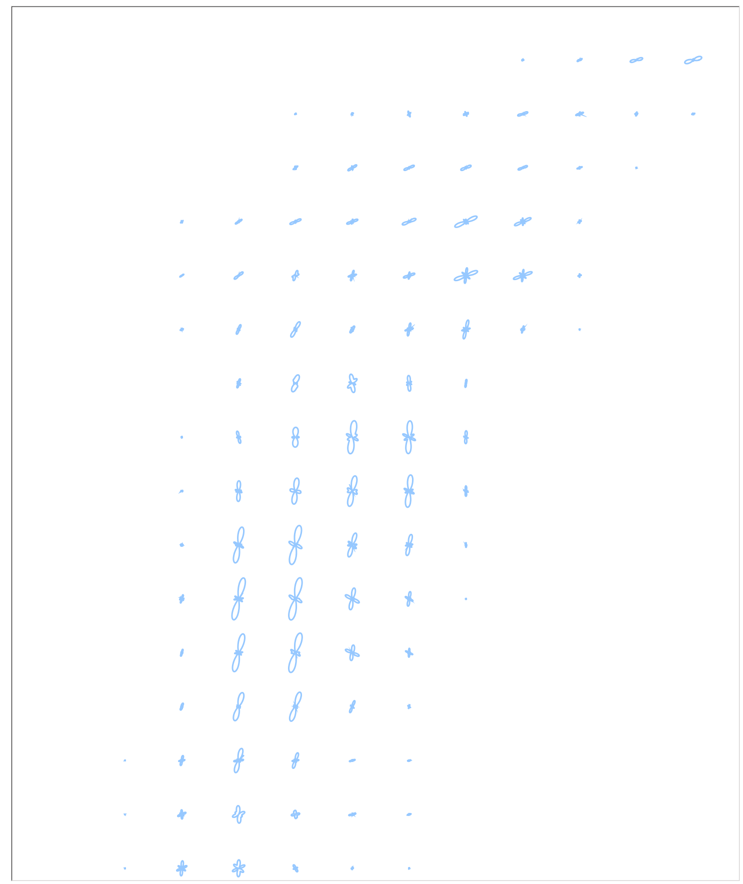
A set of 16×16 measurement mask can evidence local SPO, such as shear bands, with both intercepts and inertia tensors. It gives 256 local SPO showing with both methods the same pattern of crystal orientation indicating in this case a concentration of the magma flow in a sort of c' shear band oblique on the shear plane with local SPO parallel to the shear plane (see arrows). Thus, the automatic processing by intercepts in grey level can provide accurate SPO while saving time.



The new process of dark borders on clear background considering each border as a line with no thickness (1 pixel) is particularly useful for the analysis of fault or lineament networks. It will also benefit from the measurement mask capability to analyze local angular distributions. With 14 x 18 square masks, 252 roses of direction divided by their maximum values allow the display of a map of local faults distributions.



It could be an image of lineament or faults



Rose of directions (see course 4 p.21)

[1 3 6 8 9 9 8 6 3 1] / 54 6 [-1 1]