



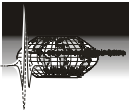
Outline

- Issue
- Formalism

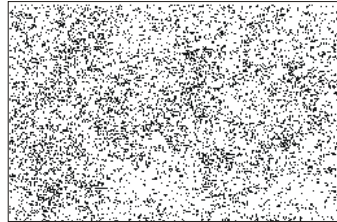
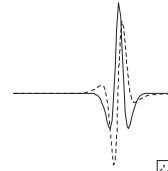
- ①D - Relative geomagnetic paleointensity
- Automatic picking of seismic phases

- ②D - Spatial distribution of seismic events
- Analysis of mineral organizations of magmatic rocks

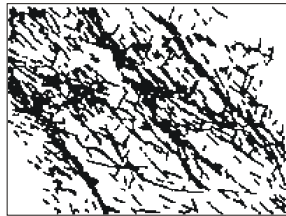
- Conclusion



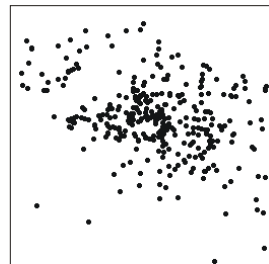
2D spatial distributions



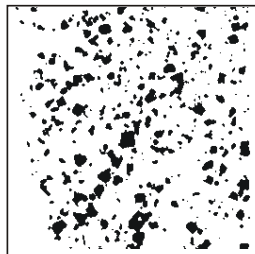
Galaxies (3000 deg²)



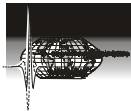
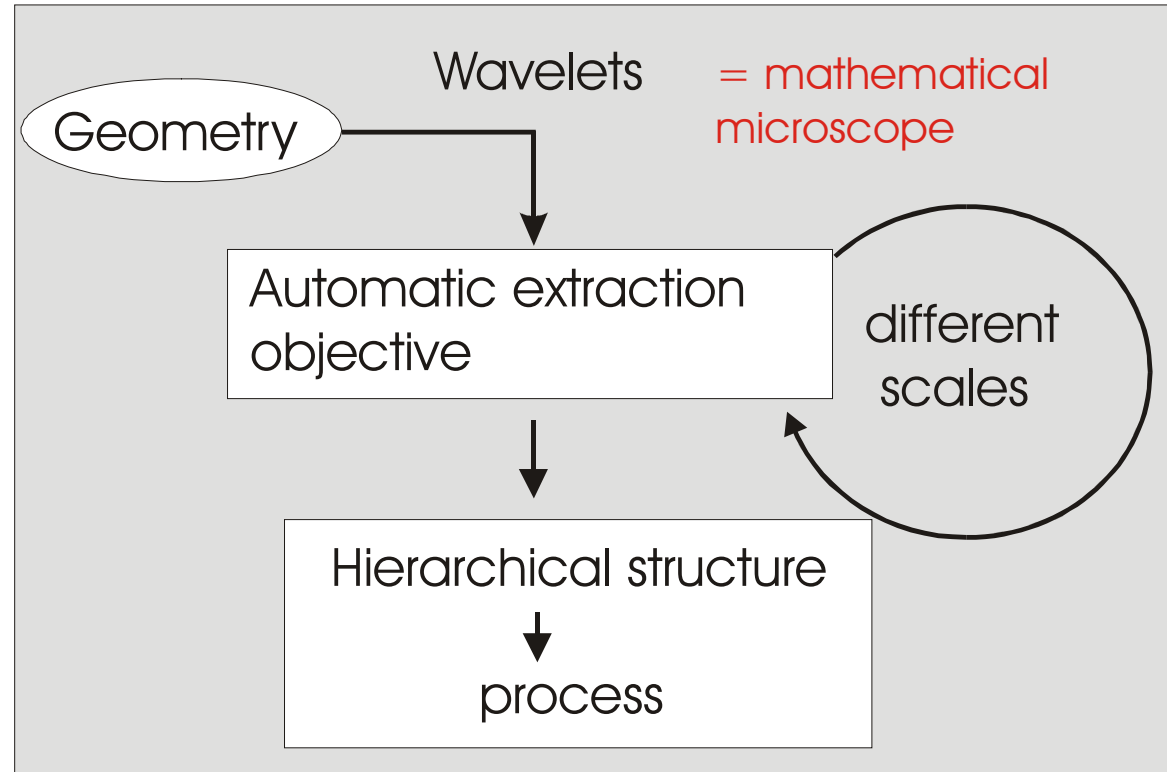
Fractures (~100 km)



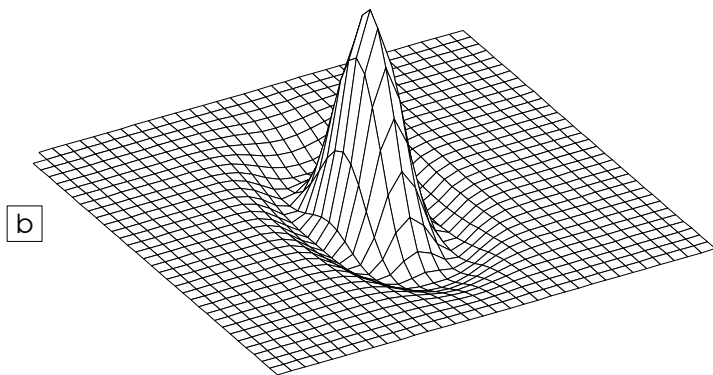
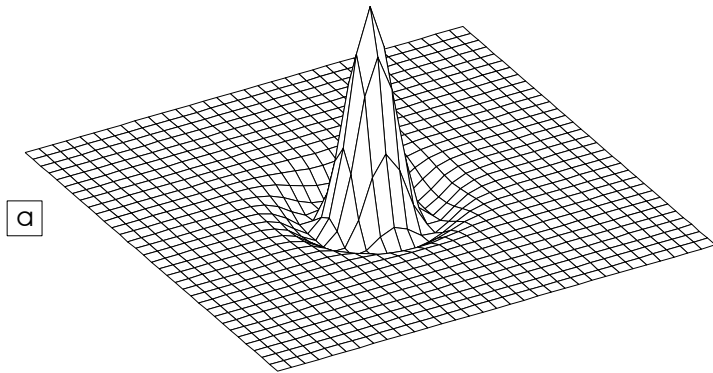
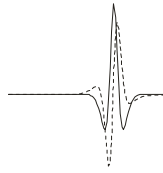
Epicenters (~km)



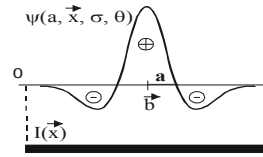
Grains (~cm)



2D anisotropic wavelets

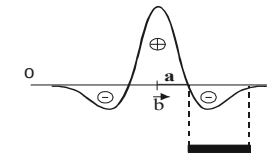


$a, b (b_x, b_y), \sigma, \theta$



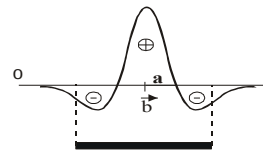
a

Null Wavelet Coefficient



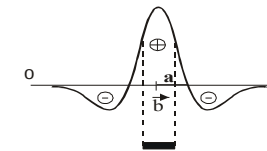
b

Negative Wavelet Coefficient



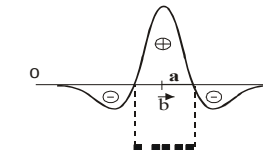
c

Weak Wavelet Coefficient



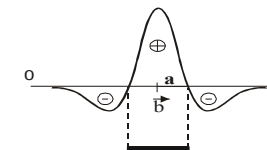
d

Weak Wavelet Coefficient



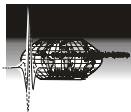
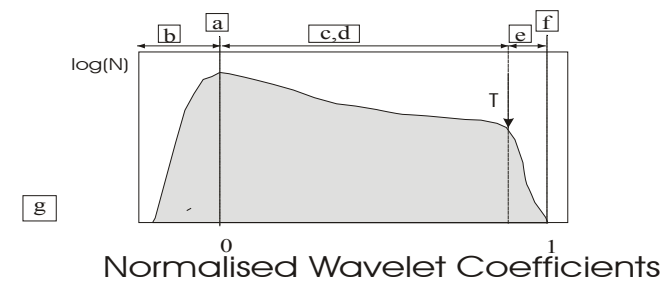
e

Strong Wavelet Coefficient



f

Maximum Wavelet Coefficient



NOAWC method

NOAWC method

For each a

For each $\sigma.a$

for each θ

- WT computation.

For each b location (b_x, b_y)

Selection of Optimum WC

Record of associated parameters
($a, \sigma.a, \theta$).

Comparison of local WC to the previously
selected NOAWC map.

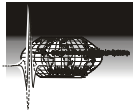
Threshold - Extraction of significant features

=> "optimised summary" at the given scale

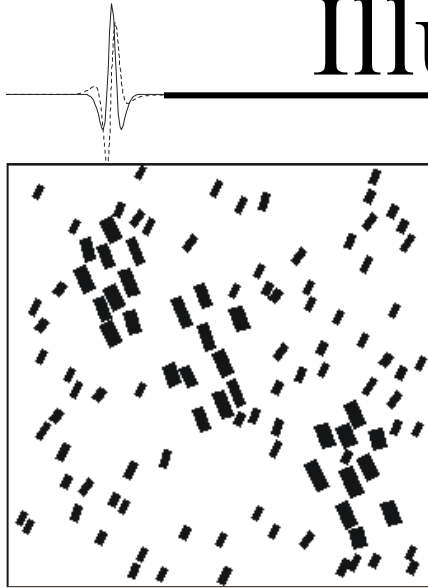
Ouillon et al. 1995, 1996

Darrozes et al., 1997

Gaillot et al., 1997



Illustration



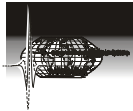
2 sub-populations of objects

Analysis parameters

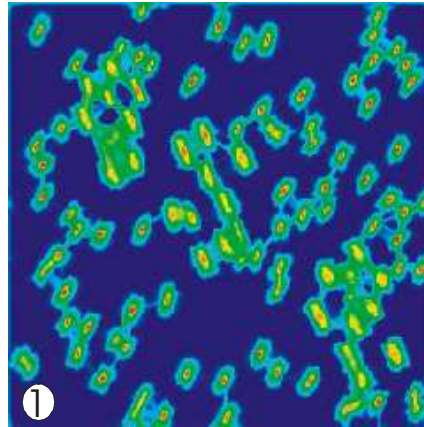
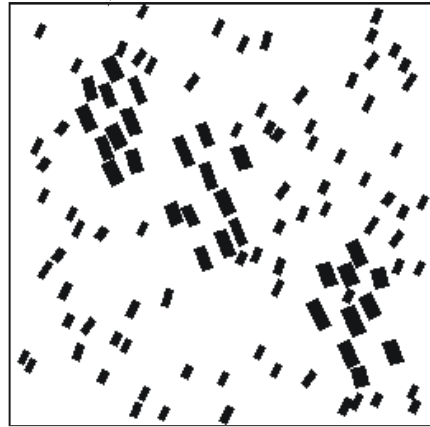
$$a = 2n \quad (n=1,2,\dots,10)$$

$$a \leq \sigma \cdot a \leq \text{image size}$$

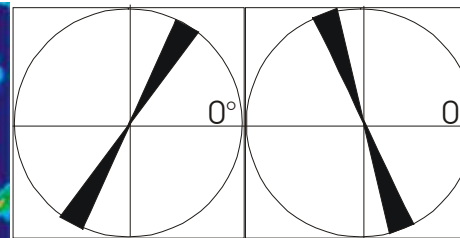
$$0^\circ \leq \theta \leq 180^\circ$$



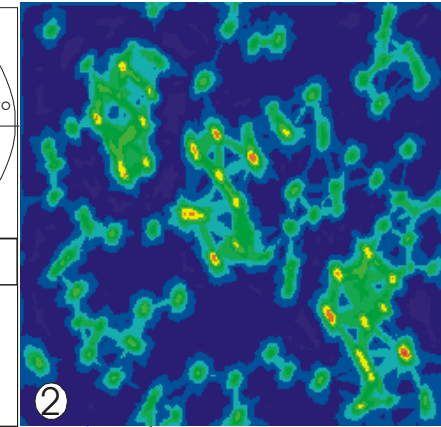
Illustration



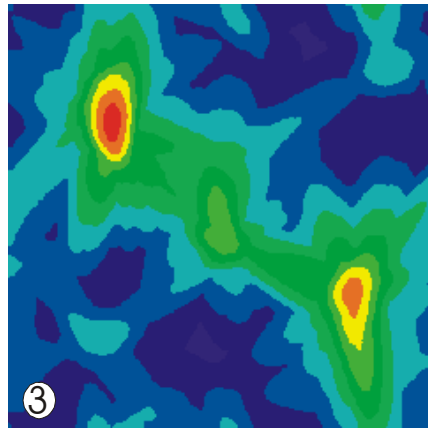
①
a= 2 pxl



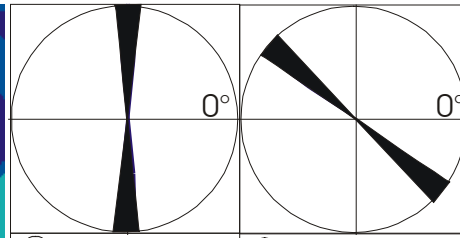
① Individual grains	②
$\alpha = 2$	$\alpha = 4$
$\theta = 60^\circ \pm 5^\circ$	$\theta = 110^\circ \pm 5^\circ$
$\sigma = 1.86 \pm 0.35$	$\sigma = 1.63 \pm 0.32$



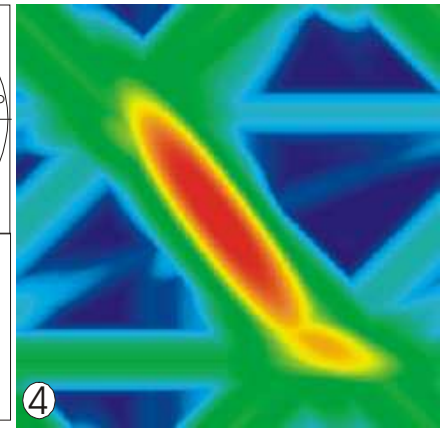
②
a= 4 pxl



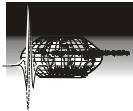
③
a= 12 pxl

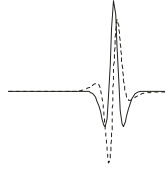


③ Clusters	④ Alignment
$\alpha = 12$	$\alpha = 16$
$\theta = 88^\circ \pm 2.5^\circ$	$\theta = 140^\circ \pm 5^\circ$
$\sigma = 1.74 \pm 0.27$	$\sigma = 3$



④
a= 16 pxl



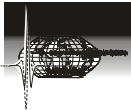


- Issue
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- ①D - Relative geomagnetic paleointensity
- Automatic picking of seismic phases

- ②D - **Spatial distribution of seismic events**
- Analysis of mineral organizations of magmatic rocks

- Conclusion

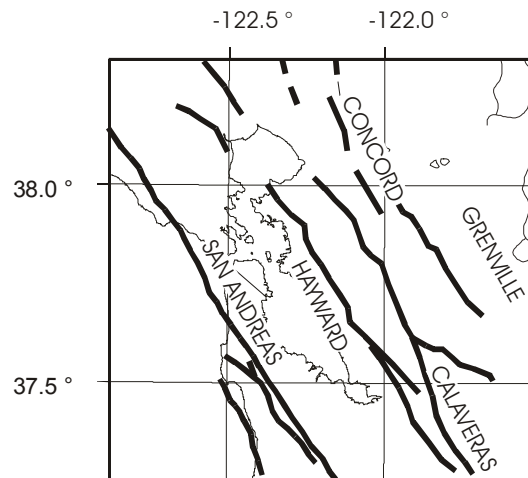


Faults and spatial distribution of seismic events

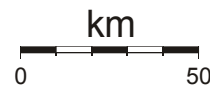
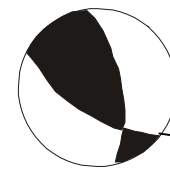
Characterization of faults

tectonics study
seismic risk

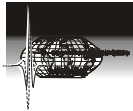
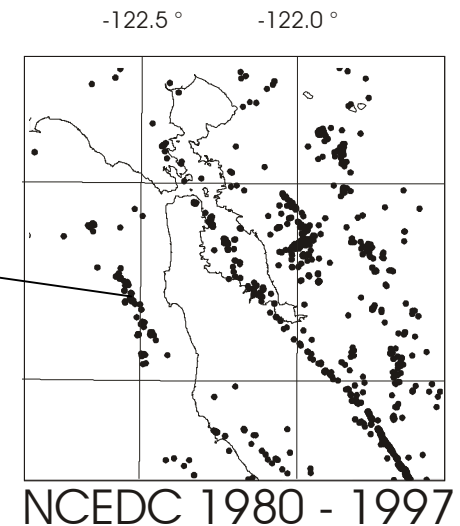
1) Field work



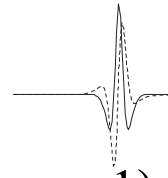
2) Focal solutions



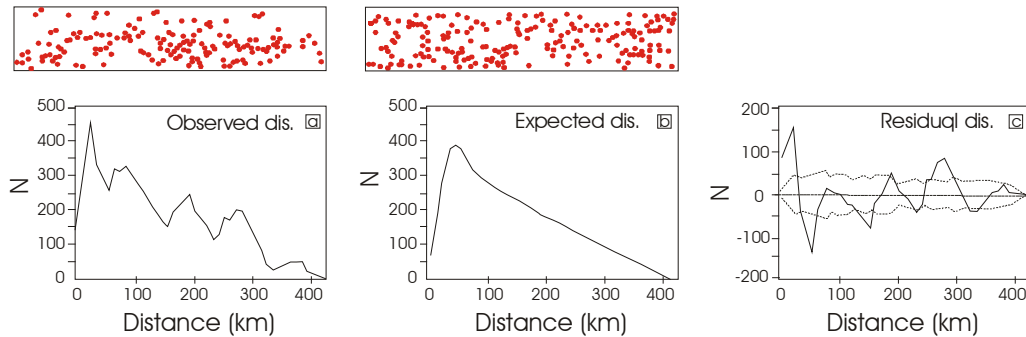
3) Spatial distribution



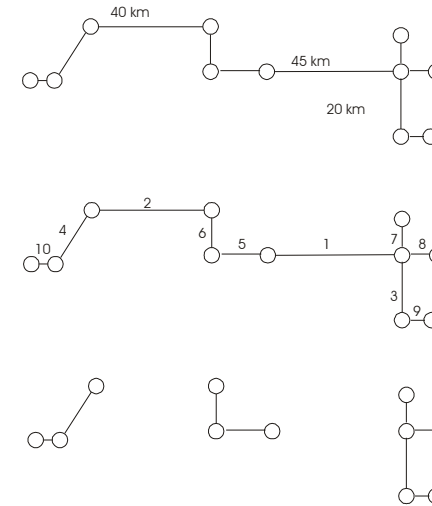
Spatial distribution analysis: methods



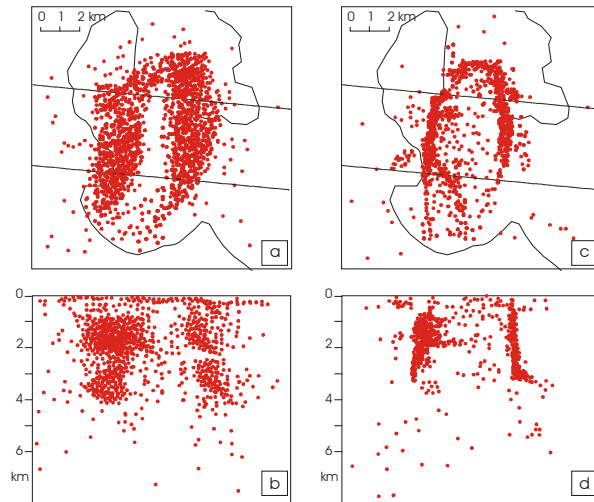
1) Statistical approach



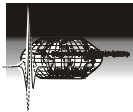
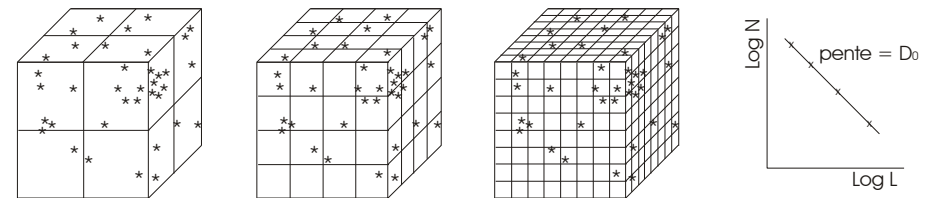
2) Single link cluster analysis



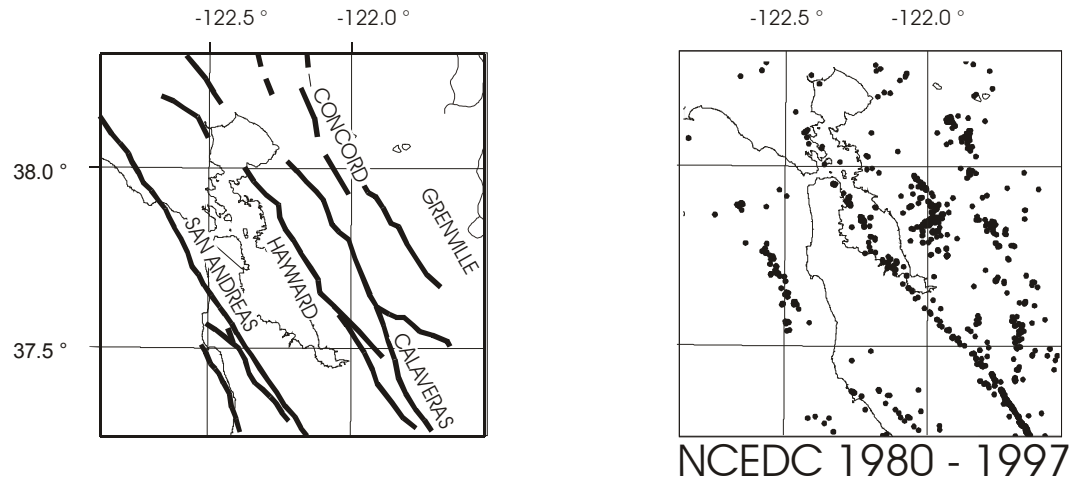
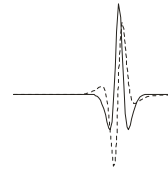
3) Collapse method



4) Fractal analysis



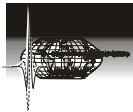
New method



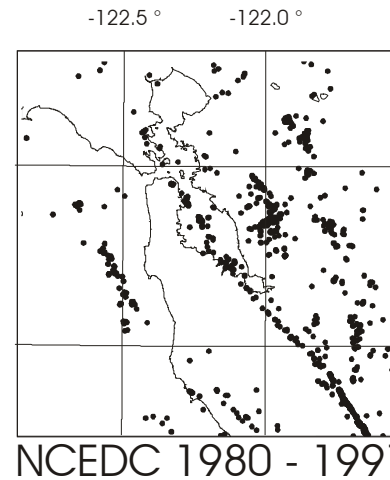
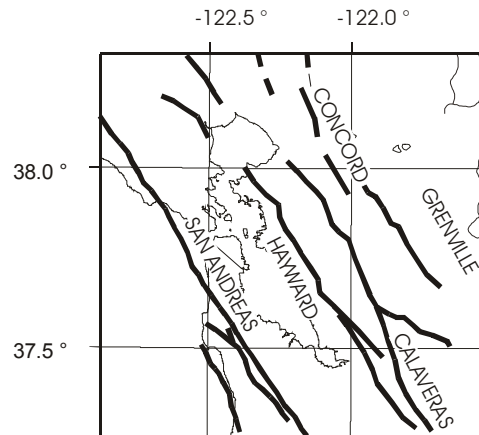
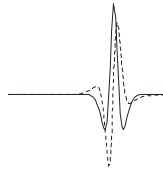
Objective detection of seismic event alignments

Hyp: alignments \longleftrightarrow fault plane

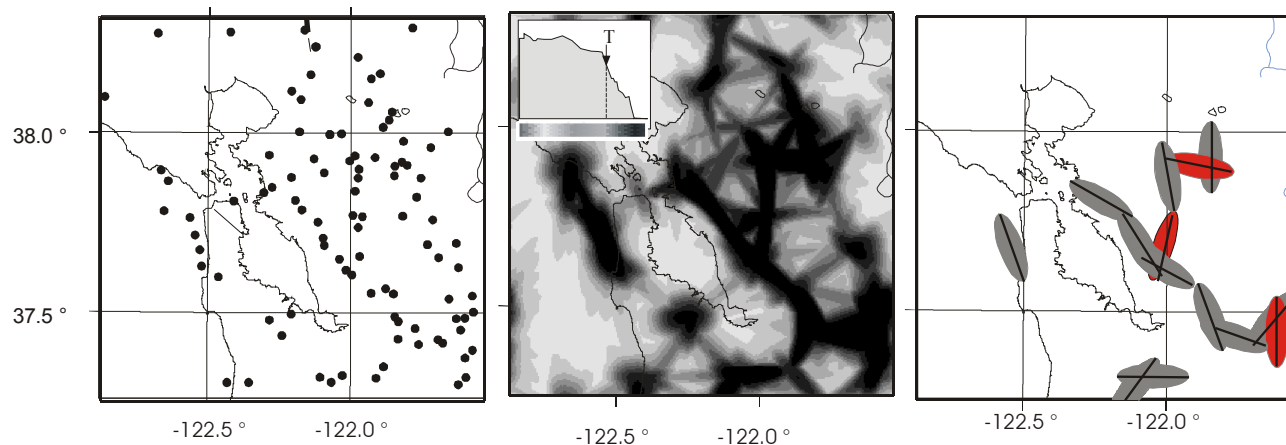
Wavelets: local azimuthal multi-scale filters



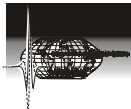
Illustration



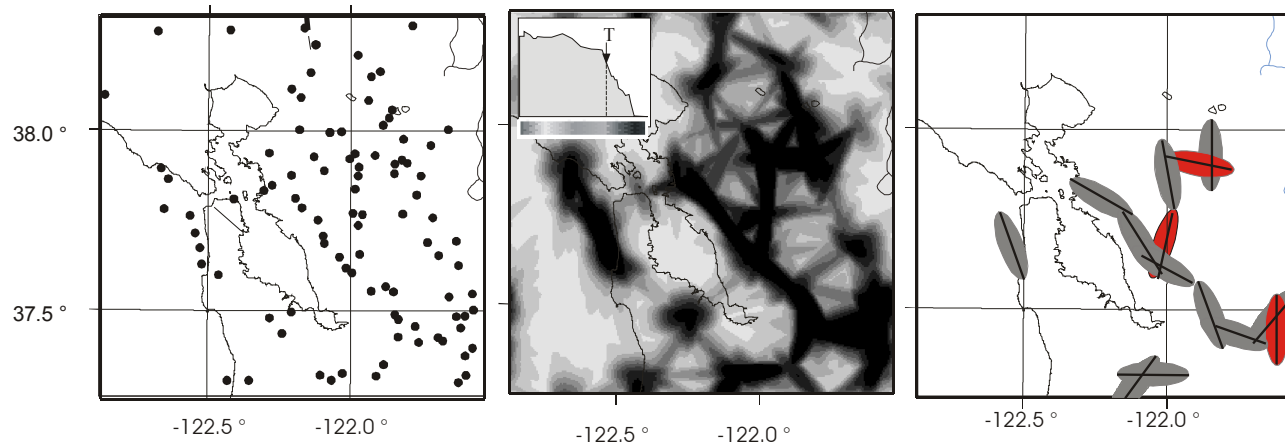
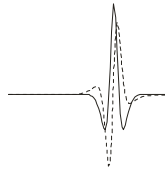
$a \sim 4 \text{ km}$
 $10 < \sigma.a < 150 \text{ km}$
 $0^\circ < \theta < 180^\circ$



100 events



Interpretation

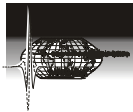


Alignments

| mapped faults
| "extra lines"

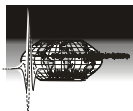
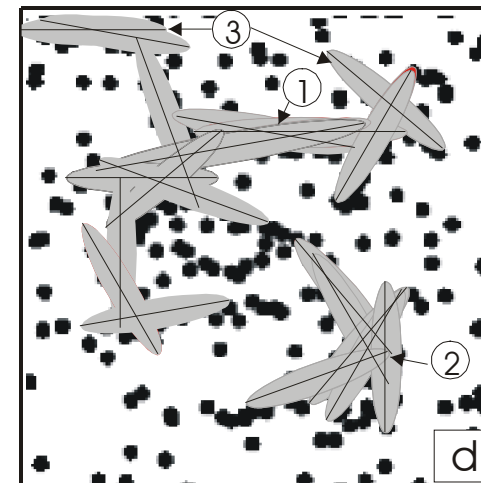
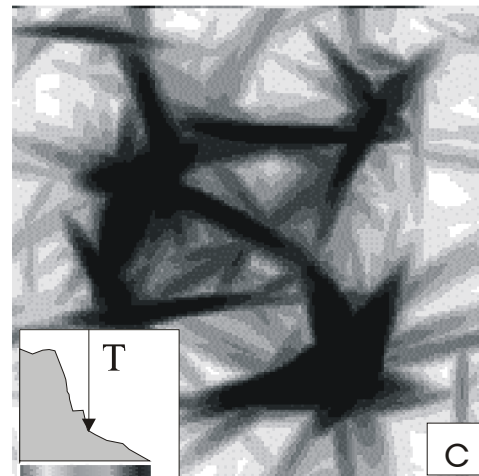
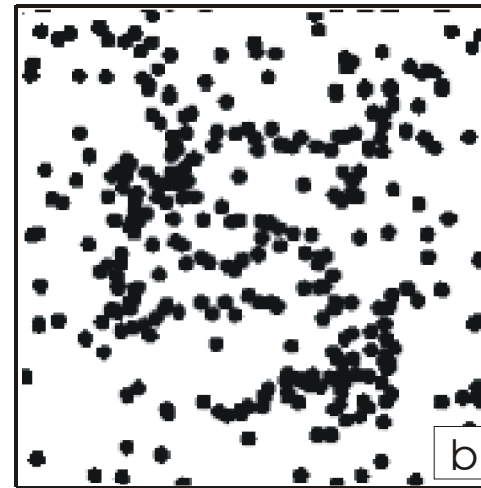
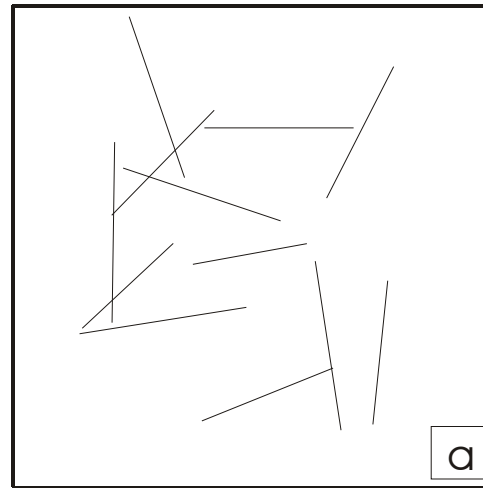
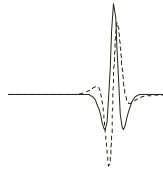
| tectonic features?
| mathematical artifacts?

Complementary investigations

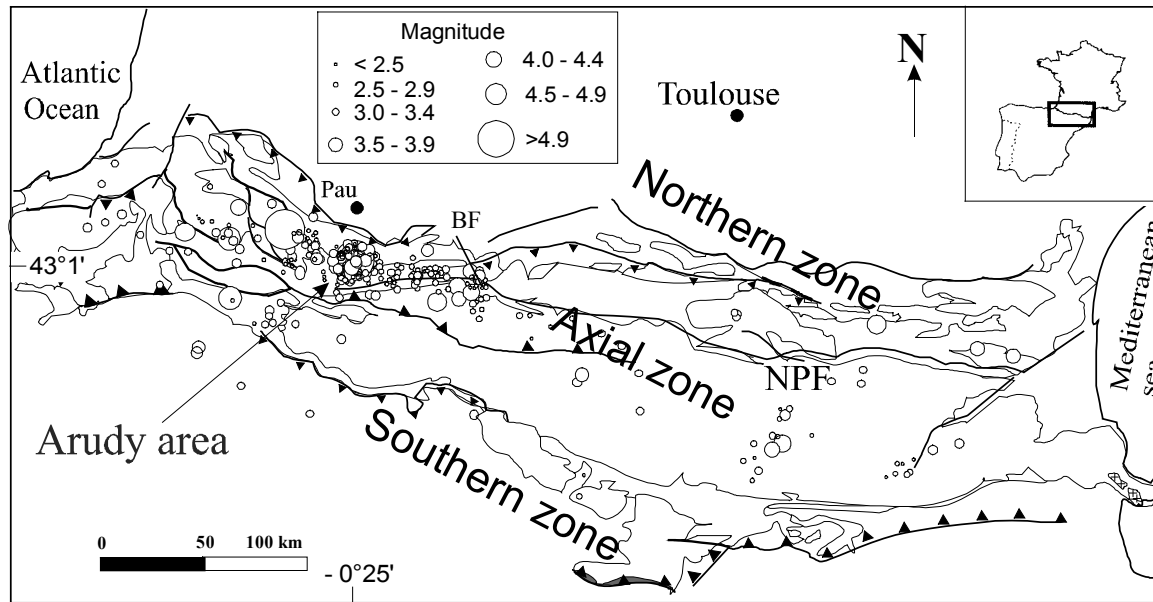


Analysis of spatial distribution of seismic events

Artifact examples



Application



Darrozes et al., 1998
Gaillet et al., in print

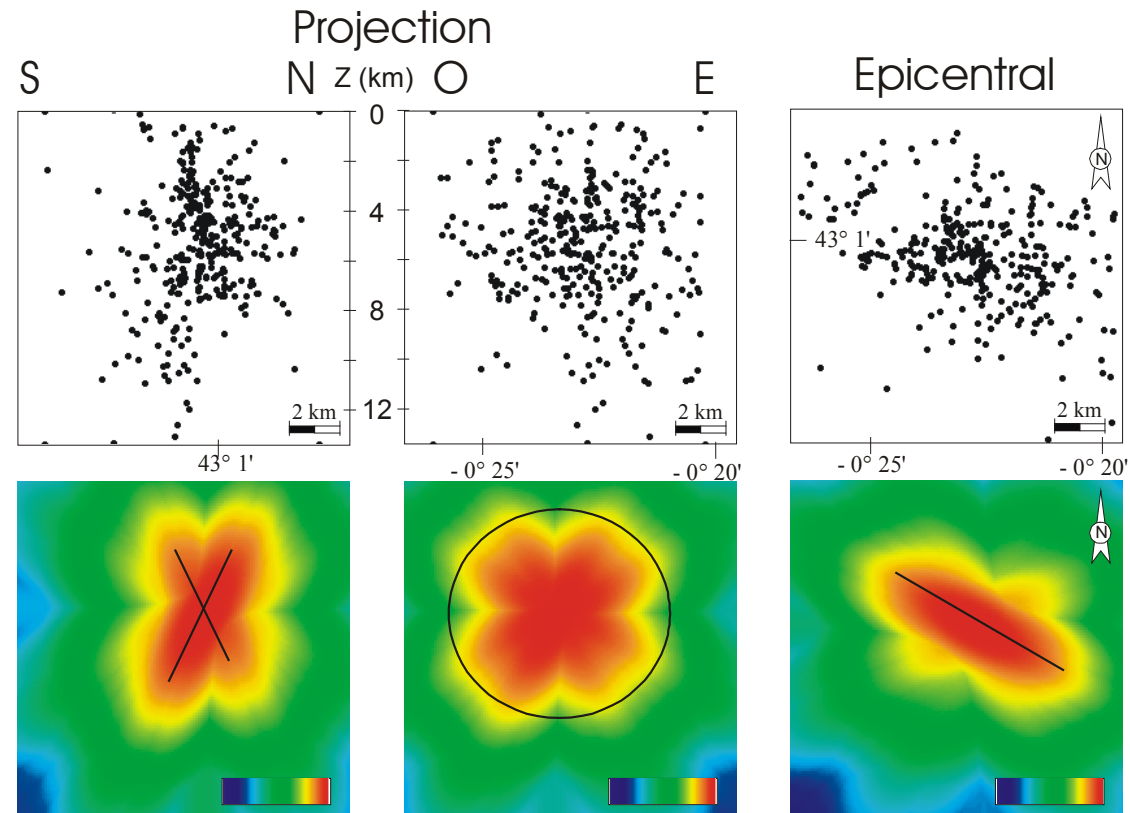
Arudy, $M = 5.1$
20/02/1980

No surface rupture
No or few mapped faults

Focal solutions
Spatial distribution of seismic events
Err Z ~ 2 km Err X, Y ~ 400 m
Gagnepain-Beyneix et al., 1982

3D → 2D

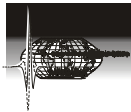
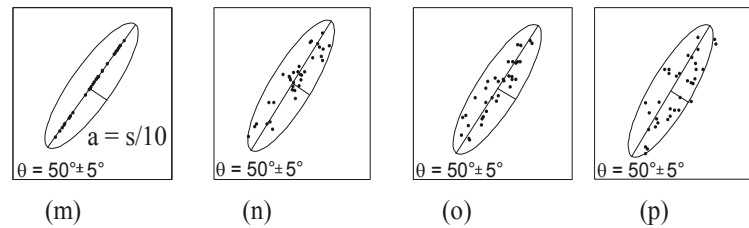
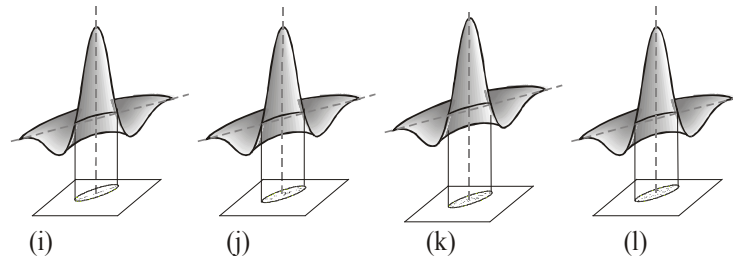
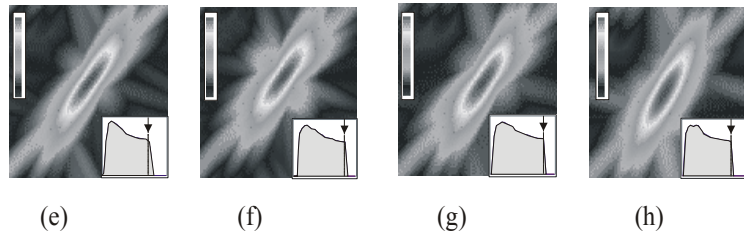
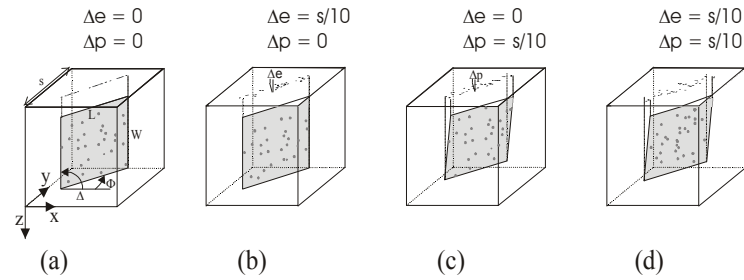
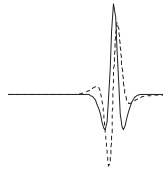
Large scale analysis



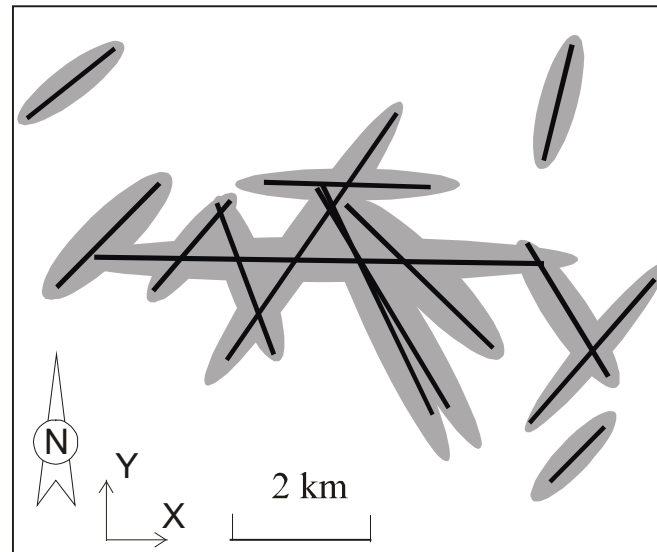
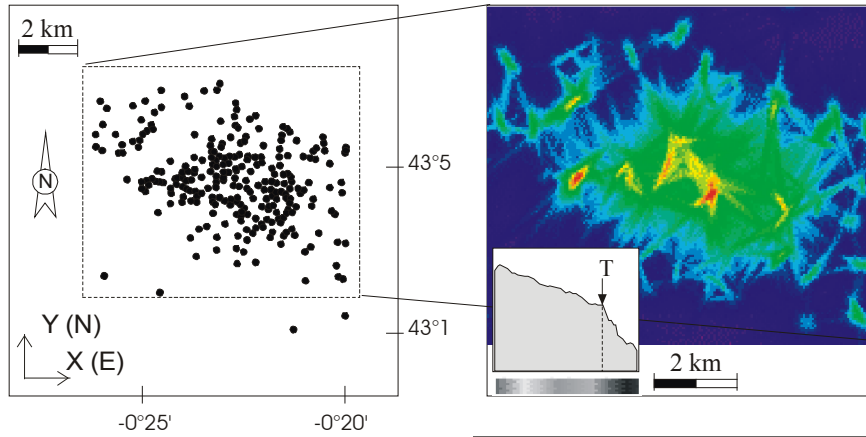
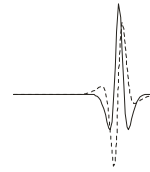
Sub vertical structures → Analysis of the epicentral distribution

Analysis of spatial distribution of seismic events

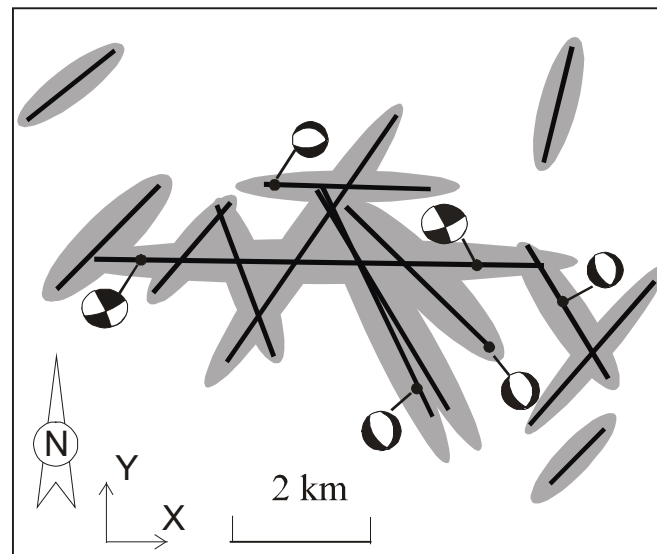
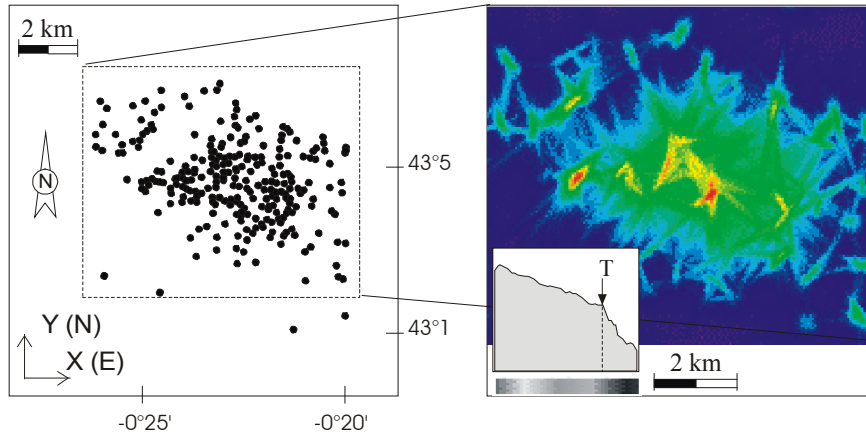
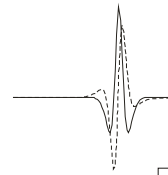
3D → 2D - theoretical cases



Epicentral distribution



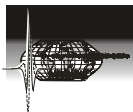
Epicentral distribution



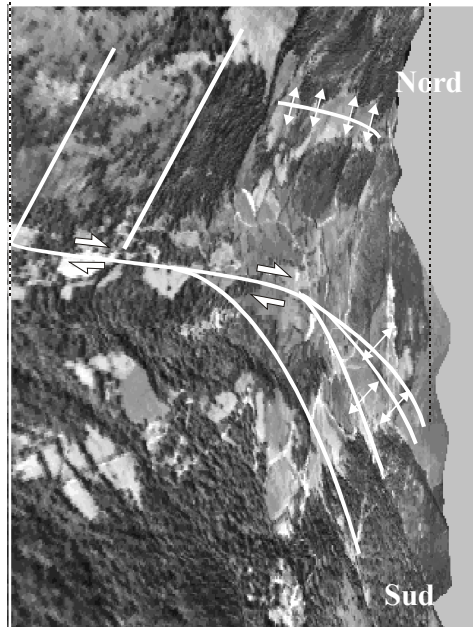
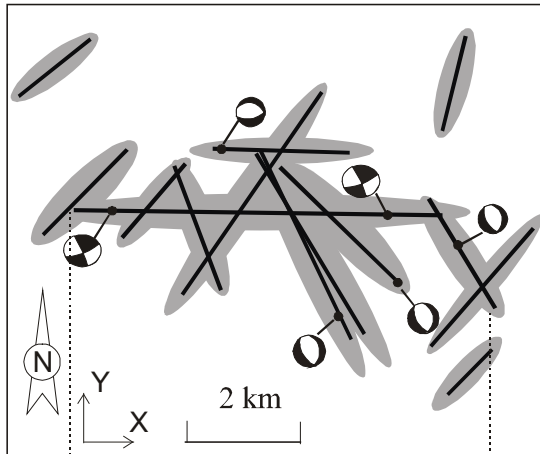
Focal solutions
Mechanical arguments



Horse tail termination



Geomorphological validation



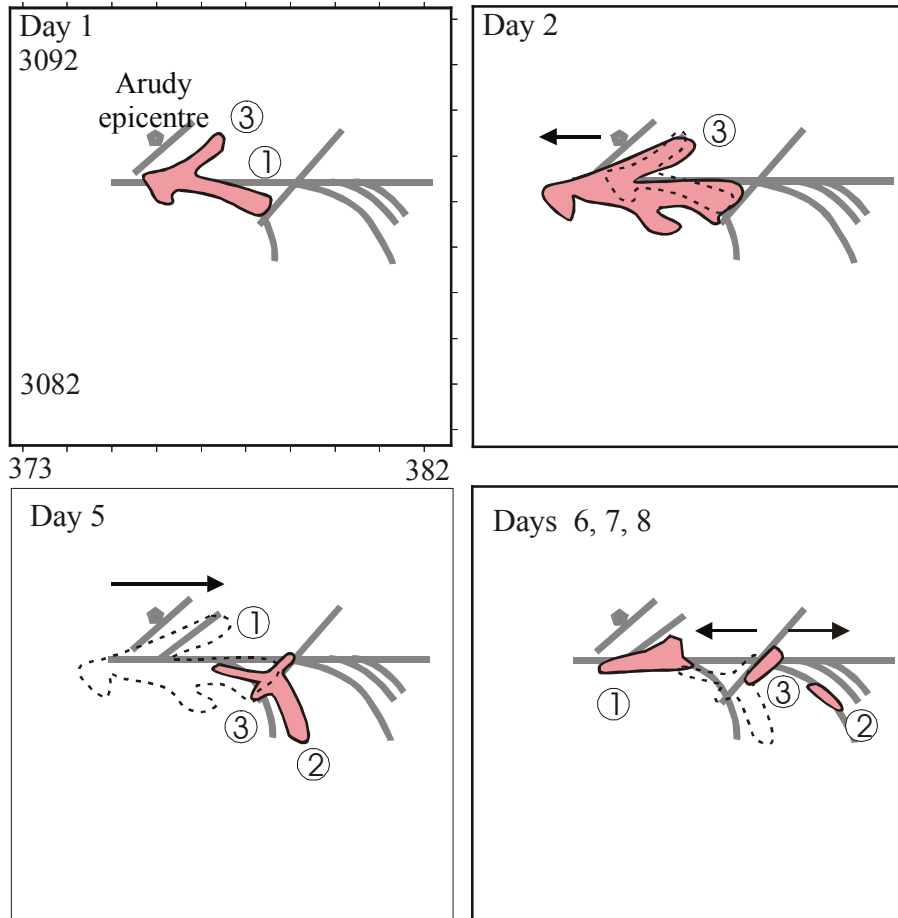
DEM
Geomorphological arguments



Validation

Fault zone mechanisms

Temporal reconstruction



Day 1: concentrated (W)
Day 2: migration to the W - Blocking
Days 3 & 4: Relaxation
Day 5: activity concentrated on the E
Days 6 &+: rebound (W)
- local reajustments (E)

Summary and Conclusion

New method

Specification

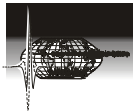
a: resolution = uncertainty on the location

Threshold value ← WC histogram

Wavelets

basis of a quantitative, objective and multi-tools approach

→ reconstruct the geometry of the rupture zone





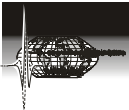
Outline

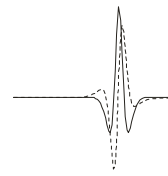
- Issue
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- ① - Relative geomagnetic paleointensity
- ① - Automatic picking of seismic phases

- ② - Spatial distribution of seismic events
- ② - **Analysis of mineral organizations of magmatic rocks**

- Conclusion





Problem

Fabric analysis

Processes

deformation of magmatic rock

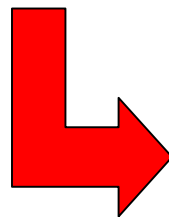
| crystallization - cooling

| liquid - solid transition

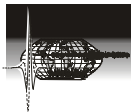
Fabric (=size, shape, orientation and spatial distribution)

| significance at grain scale

| acquisition mechanisms



Cinematic and tectonic studies of the upper crust



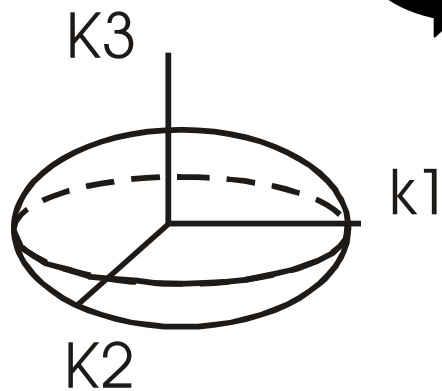
Classical approaches

Field work

AMS

3D

Magnetic phases



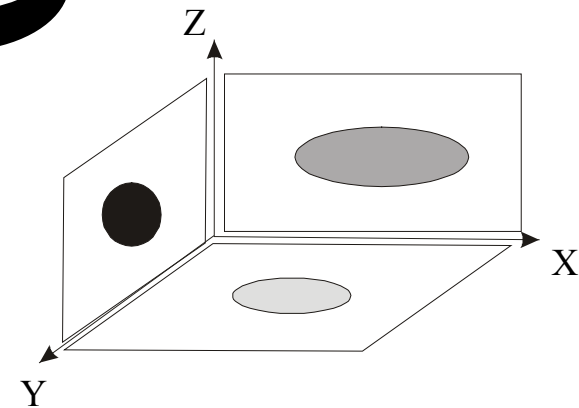
composition
size
shape
orientation
spatial distribution

TENSORS

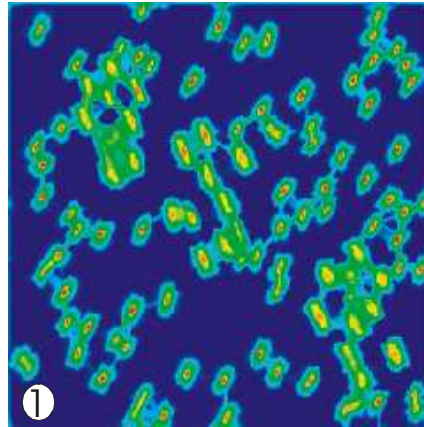
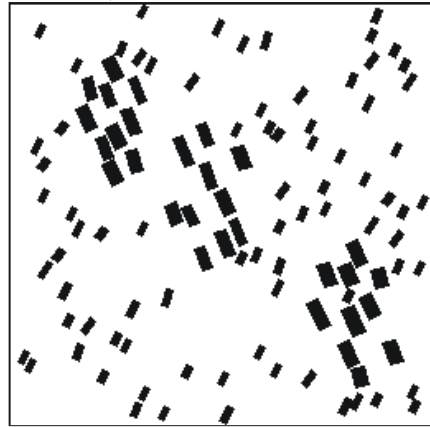
Image analysis

2D

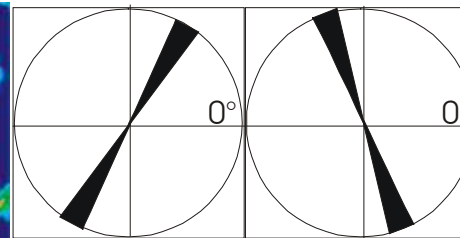
All phases



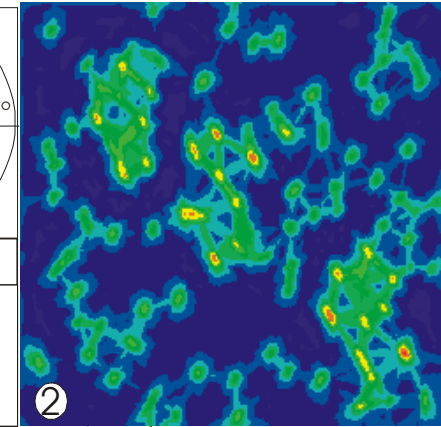
Method



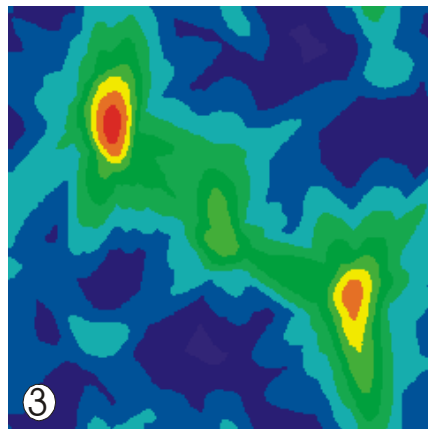
①
a= 2 pxl



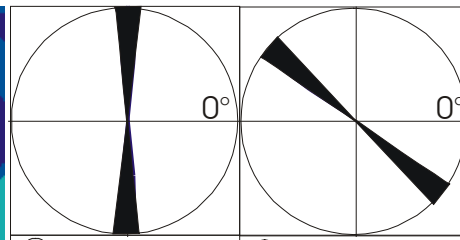
① Individual grains	②
$\alpha = 2$	$\alpha = 4$
$\theta = 60^\circ \pm 5^\circ$	$\theta = 110^\circ \pm 5^\circ$
$\sigma = 1.86 \pm 0.35$	$\sigma = 1.63 \pm 0.32$



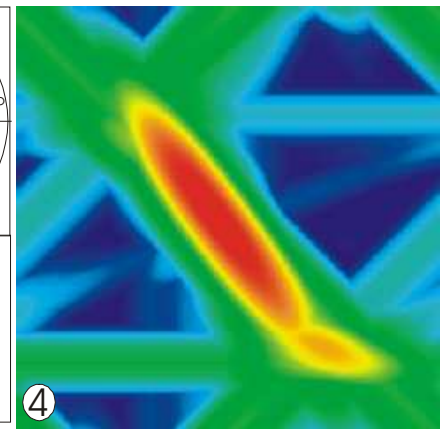
②
a= 4 pxl



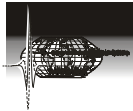
③
a= 12 pxl



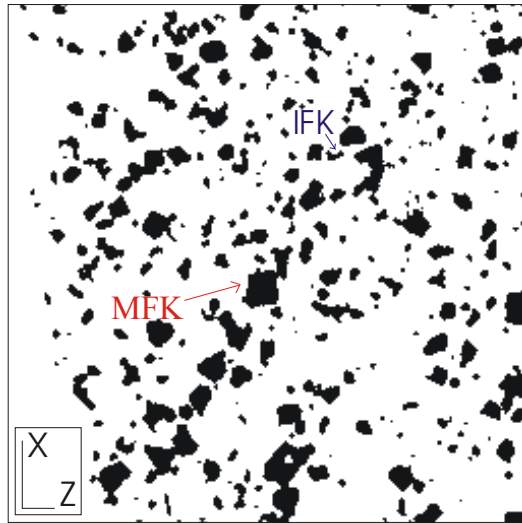
③ Clusters	④ Alignment
$\alpha = 12$	$\alpha = 16$
$\theta = 88^\circ \pm 2.5^\circ$	$\theta = 140^\circ \pm 5^\circ$
$\sigma = 1.74 \pm 0.27$	$\sigma = 3$



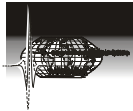
④
a= 16 pxl



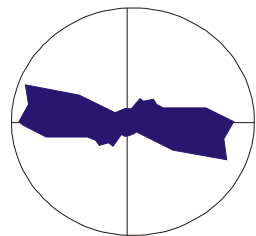
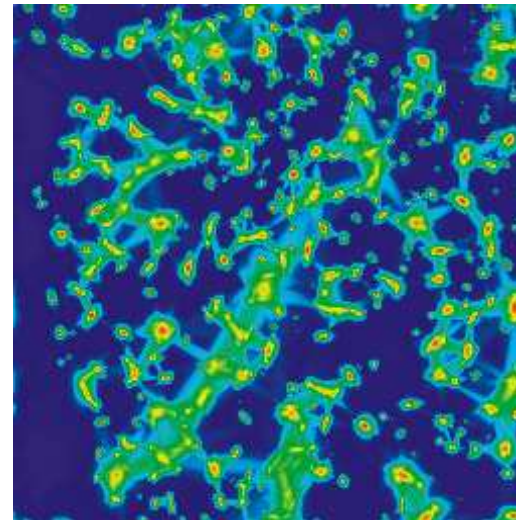
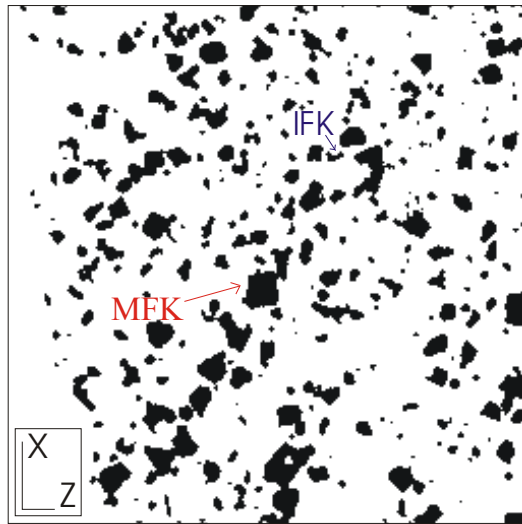
Application



Granite XZ section (Sidobre, France)
20 cm x 20 cm
Potassium Feldspar



Results

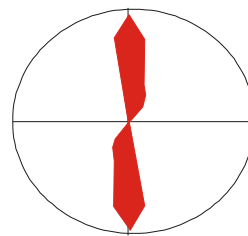


FP interstitial:

$a = 2 \text{ pxl}$

$SR = 1.3 \pm 0.3$

$\Theta = -10^\circ \pm 5$

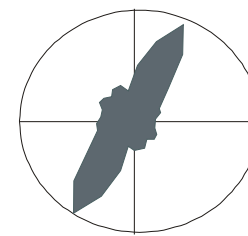


FP Megacrystals:

$a = 4 \text{ and } 6 \text{ pxl}$

$SR = 1.2 \pm 0.2$

$\Theta = 90^\circ \pm 5$



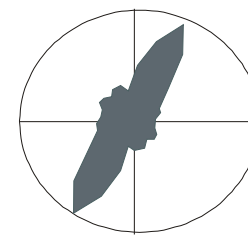
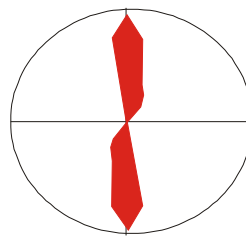
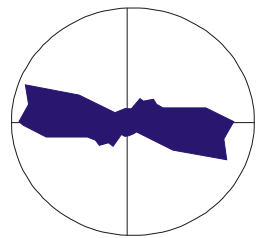
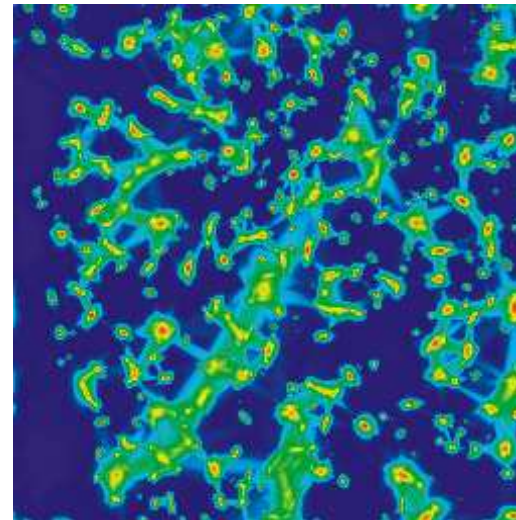
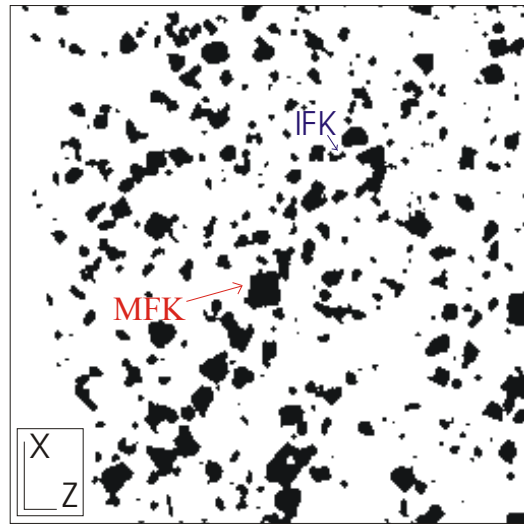
Alignments:

$a = 8 \text{ and } 10 \text{ pxl}$

$SR = 8 \pm 2.4$

$\Theta = 30 \pm 5$

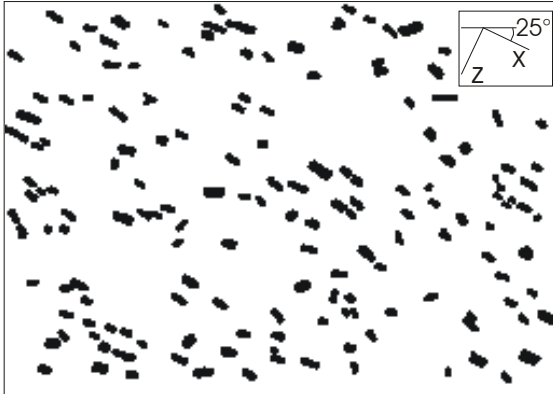
Interpretation



Recognition of 2 perpendicular sub-fabrics ← late crystallization processes with infilling of microcracks by the last feldspathic liquids



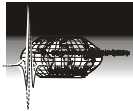
Application



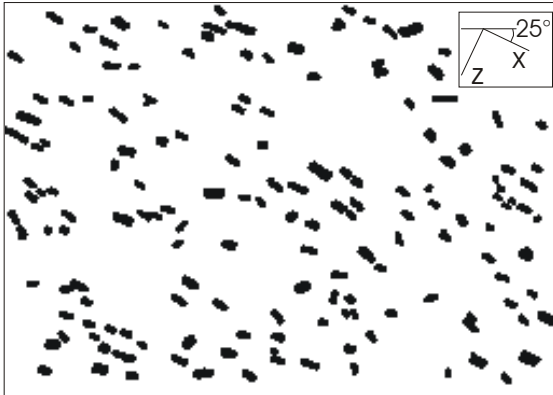
Granite XZ section (Sidobre, France)

70 cm x 100 cm

Potassium Feldspar

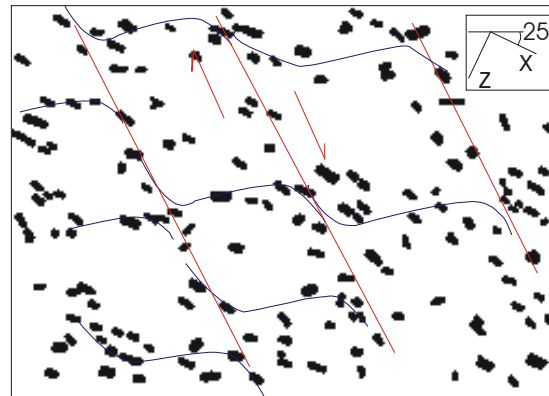
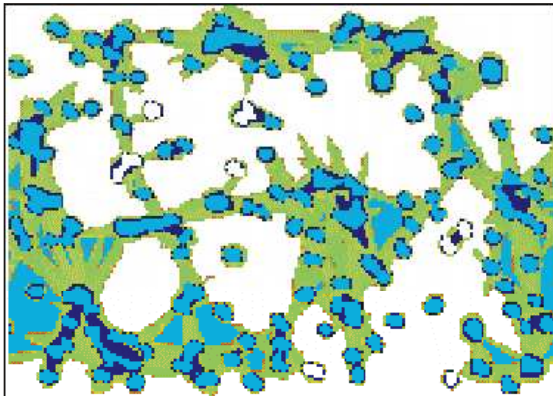


Results



Periodical spatial distribution

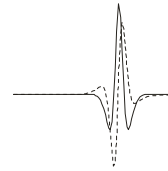
sliding at the grain/matrix interface
mechanical interactions between grains



Shear before complete crystallization of the massif



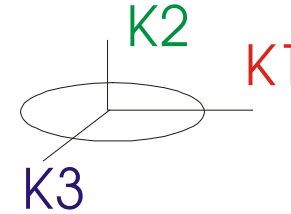
Magnetite spatial distribution and AMS



2 isolated grains



shape
orientation
size



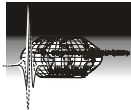
Spatial distribution and AMS? Theoretical

Stephenson, 1991
Canon-Tapia, 1995

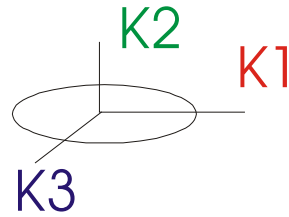
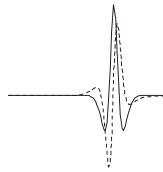
Experimental

Hargraves, 1991
Grégoire et al., 1995

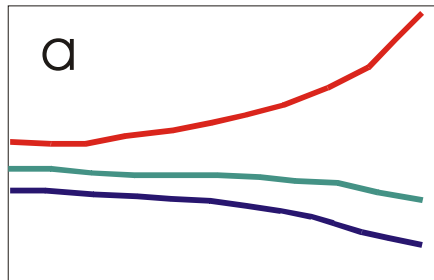
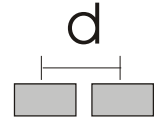
Magnetic interaction



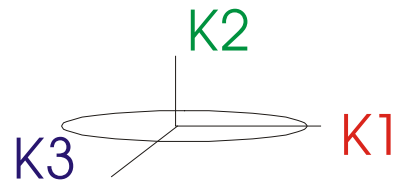
Magnetic interaction



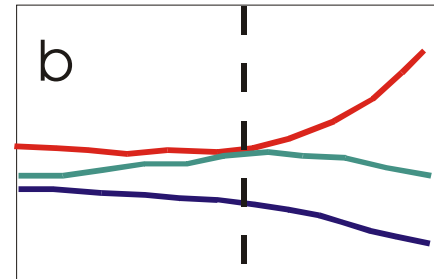
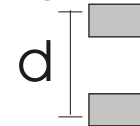
configuration a



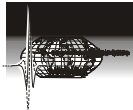
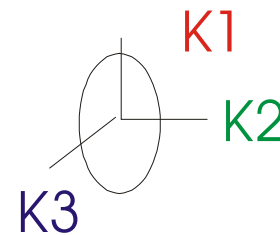
1/d



configuration b

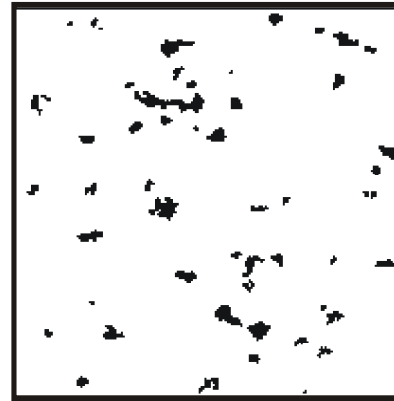


1/d



Natural case

Syenite (Madagascar)
3% magnetite content



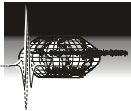
2 cm x 2 cm

6 K1K2 sections

6 K2K3 sections

6 K1K3 sections

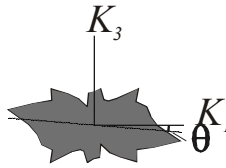
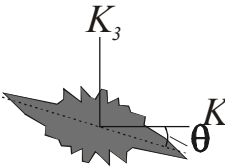
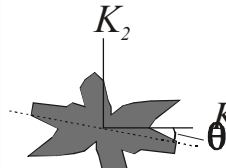
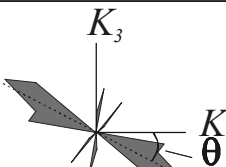
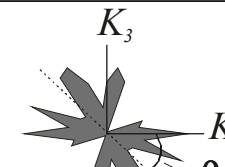
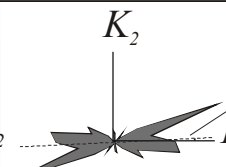
600 grains



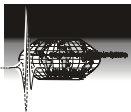
Analysis and Results

Wavelets =

- local azimuthal filters
- detect and characterize interacting clusters
 - inter-grains distance
 - orientation of the alignment

		K_1K_3	K_2K_3	K_1K_2
Weak interactions	$C \geq 0.22$			
	θ ($^\circ$) n (%)	5 ± 22 20.1	14 ± 22 19.3	11 ± 22 18.7
Strong interactions	$C \geq 0.42$			
	θ ($^\circ$) n (%)	28 ± 11 3.8	46 ± 11 2.7	-3 ± 6 5.5

ASM = SPO





Summary and Conclusion

Processes of magmatic rock deformation

Results

developed method

Quantify

SPO

spatial distribution of grains

Distinguish different sub-fabrics

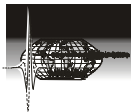
Detect structures of various scales

Late crystallization processes

sliding at the grain/matrix interface

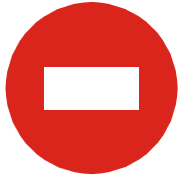
mechanical interaction between grains

validate AMS use for ferromagnetic rocks



Conclusion : Methodological point of view

Local and multi-scale analysis - No hypothesis - Flexibility



Theoretical considerations

formalism

mathematical restrictions

knowledge of the system



Explain nothing - Unravel mixed information

Quantitative description

heterogeneities, singularities and interactions
at different scales



PROCESSES