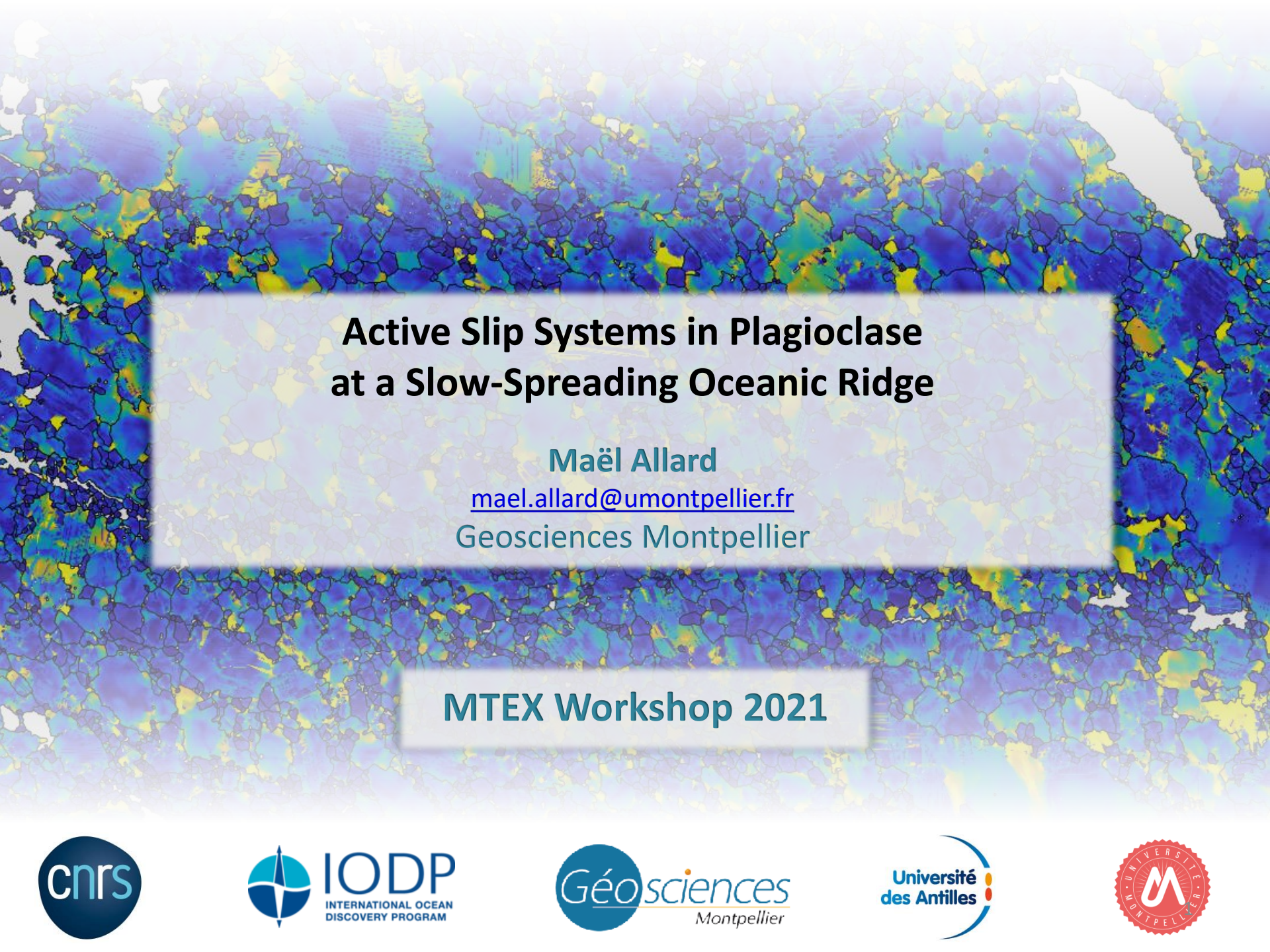

Active Slip Systems in Plagioclase at a Slow-Spreading Oceanic Ridge

Maël Allard
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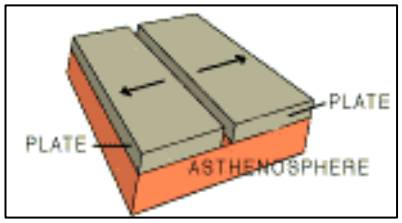
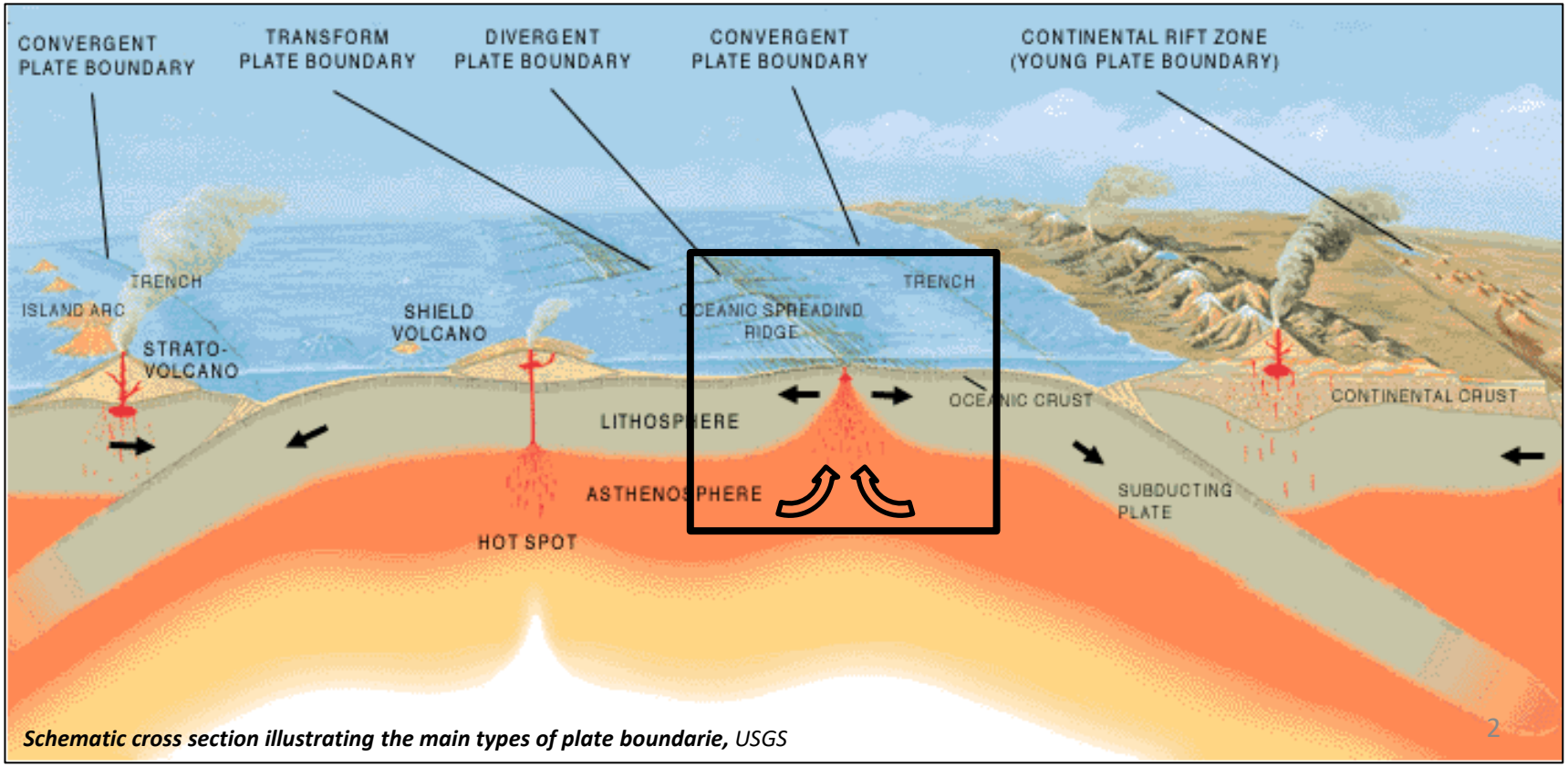
Geosciences Montpellier

MTEX Workshop 2021

Mid-ocean ridges

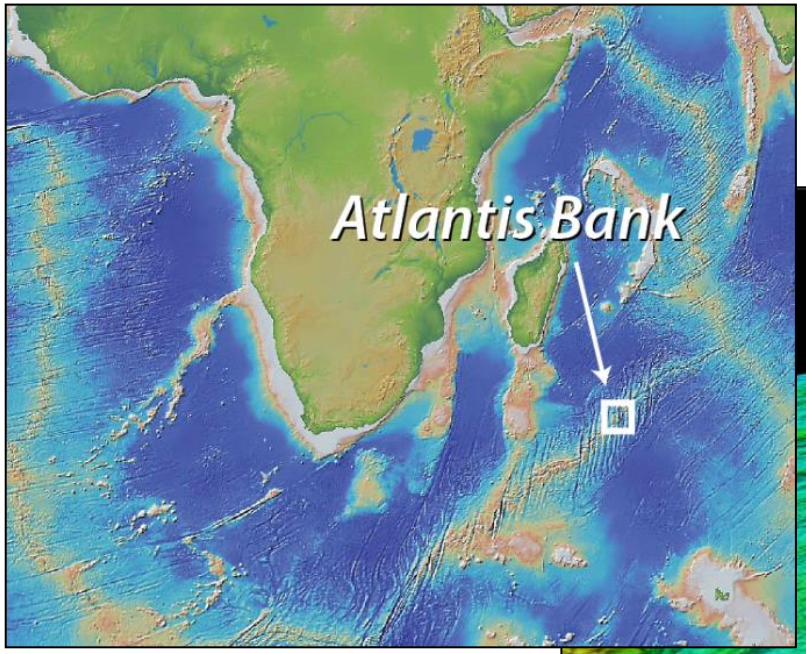
- Divergent tectonic plate boundary
- Create ocean crust by accretion



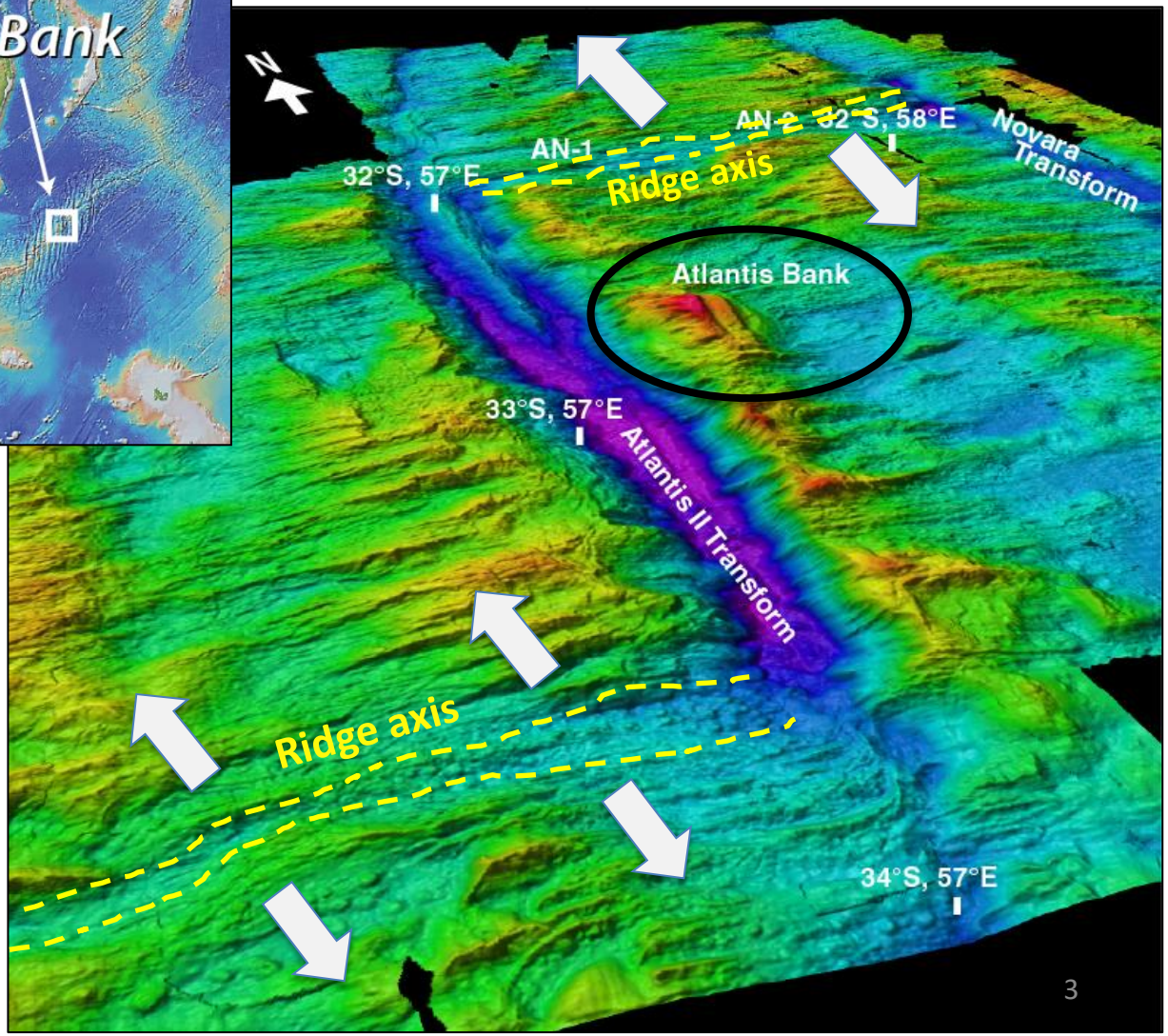


Schematic cross section illustrating the main types of plate boundarie, *USGS*

Studied area



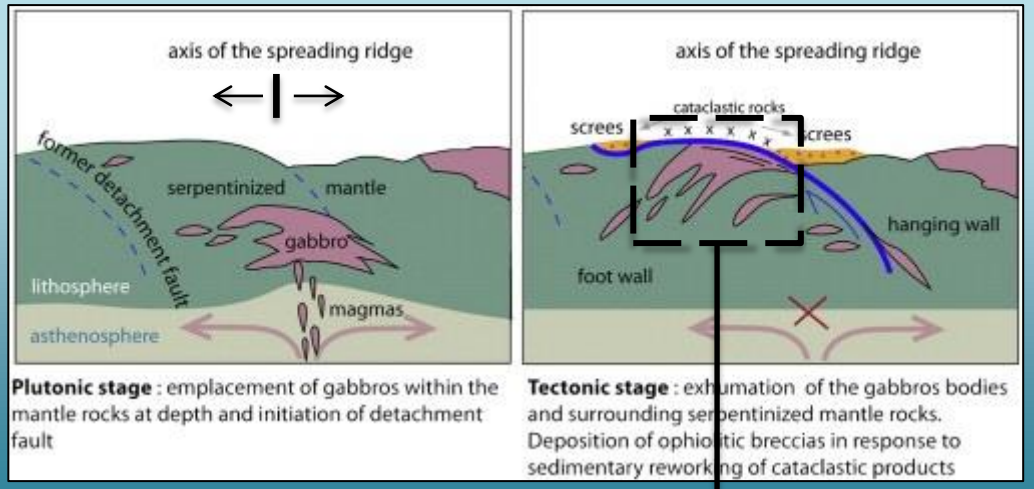
Location map of the Atlantis Bank, *background map from GEBCO database*



Bathymetric map of Atlantis II Transform in the Indian Ocean *(Dick et al., 2017)*

Formation of an Oceanic Core Complex

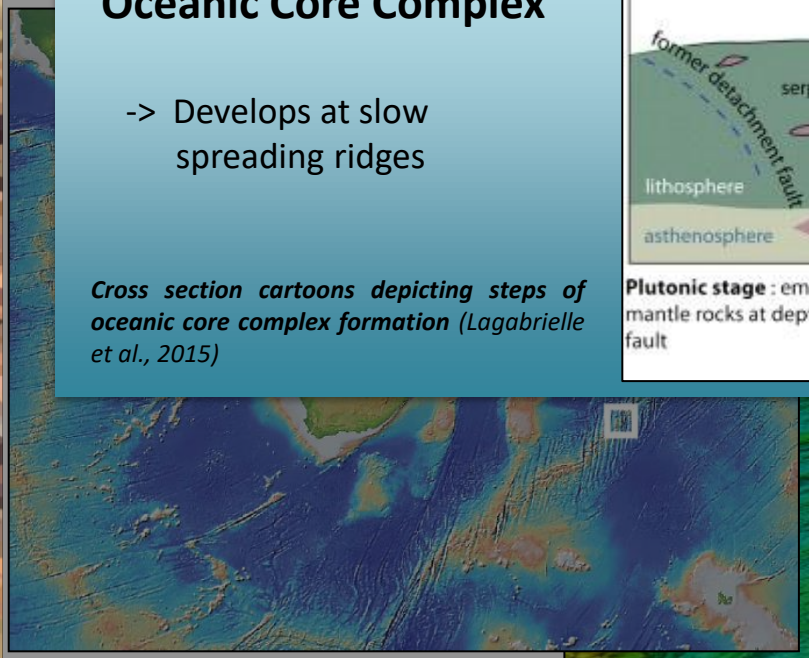
-> Develops at slow spreading ridges



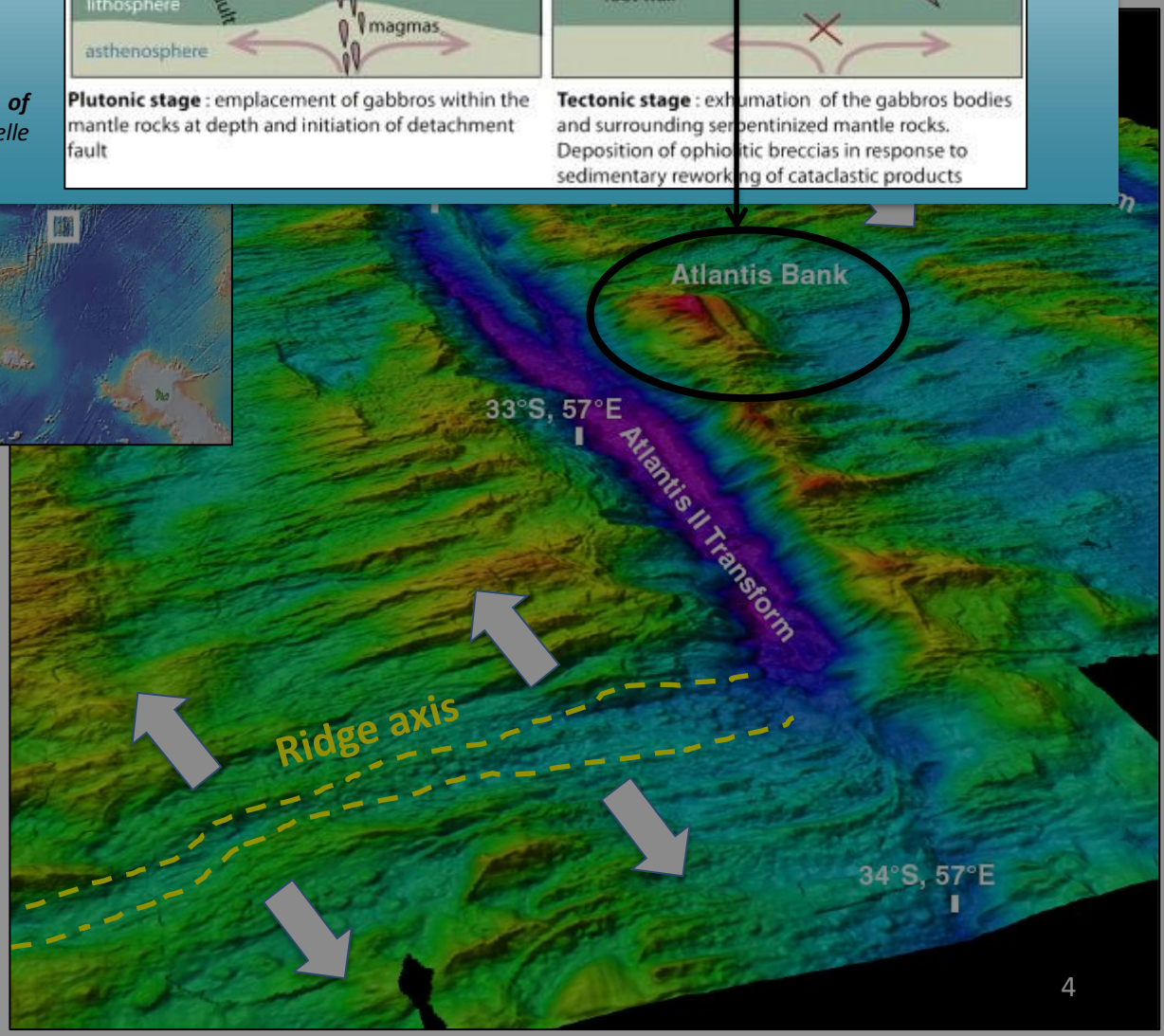
Plutonic stage : emplacement of gabbros within the mantle rocks at depth and initiation of detachment fault

Tectonic stage : exhumation of the gabbros bodies and surrounding serpentinized mantle rocks. Deposition of ophiolitic breccias in response to sedimentary reworking of cataclastic products

Cross section cartoons depicting steps of oceanic core complex formation *(Lagabrielle et al., 2015)*

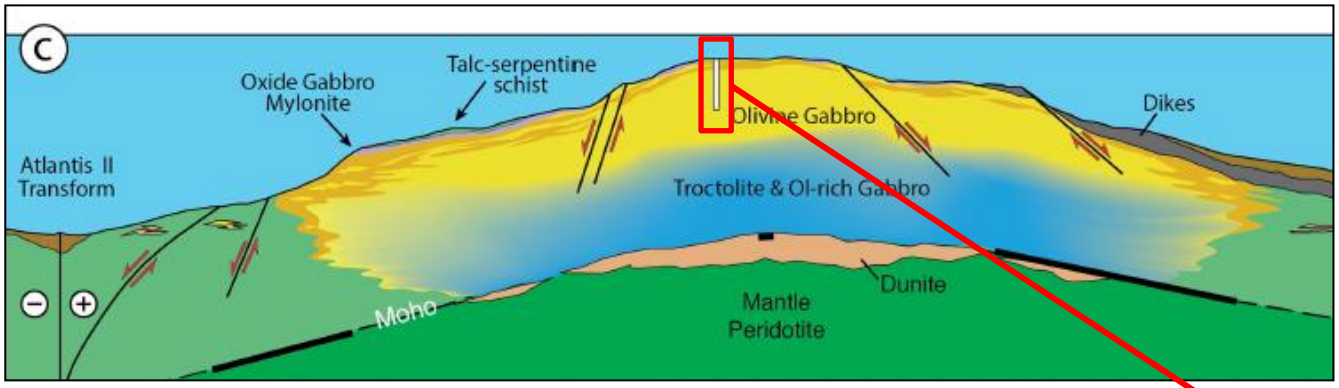


Location map of the Atlantis Bank, *background map from GEBCO database*



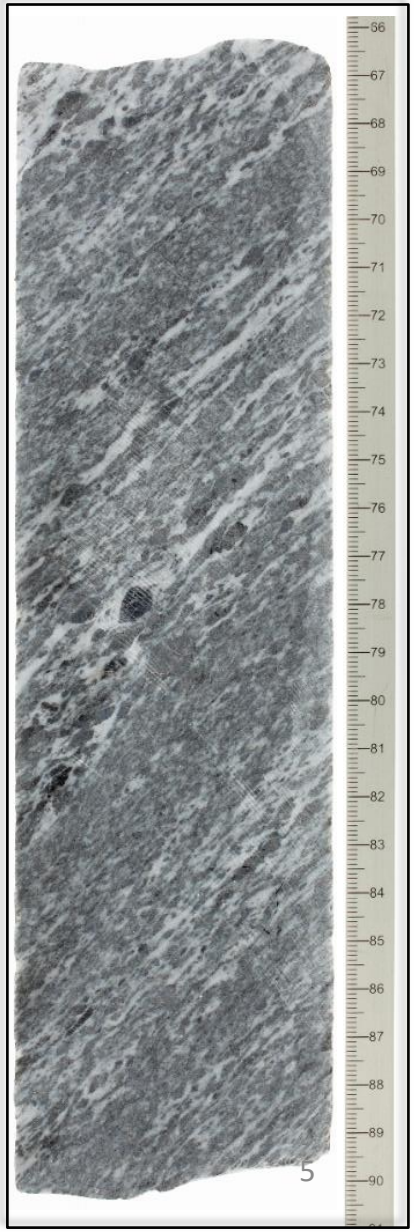
Bathymetric map of Atlantis II Transform in the Indian Ocean *(Dick et al., 2017)*

Objectives



East-West cross-section of Atlantis Bank *through Hole 735B based on the seafloor geology and ODP and IODP drill cores (Dick et al., 2019)*

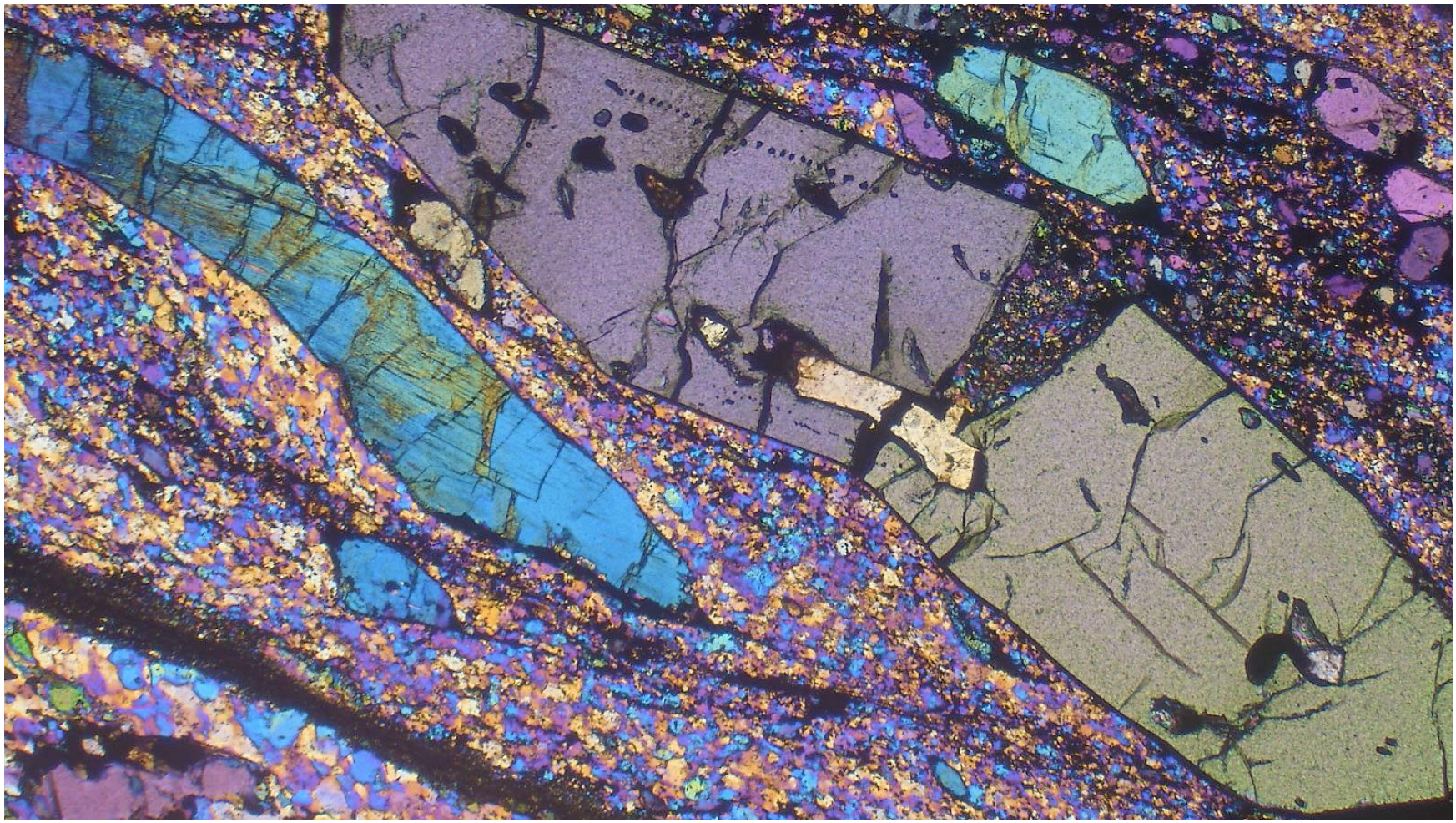
Drilled cores



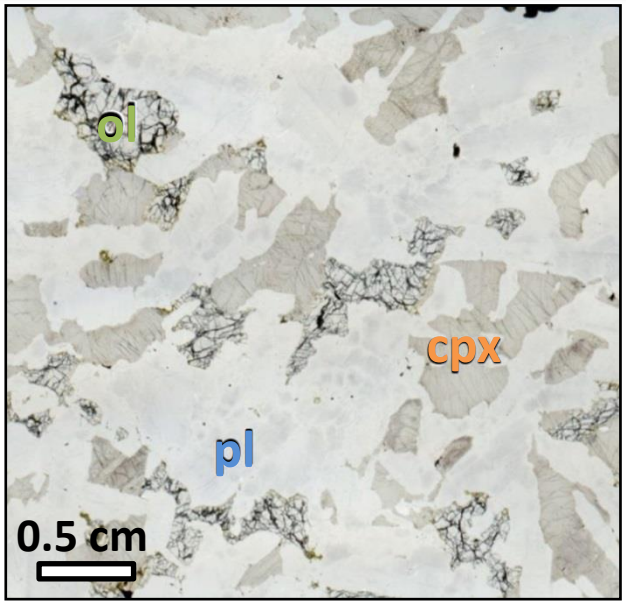
Aims:

- **Analyse ductile deformation of gabbros during accretion & exhumation**
  - ➢ Constrain the main deformation mechanisms
  - ➢ Identify the active slip systems in plagioclase at high temperatures

Petrography
&
Microstructure

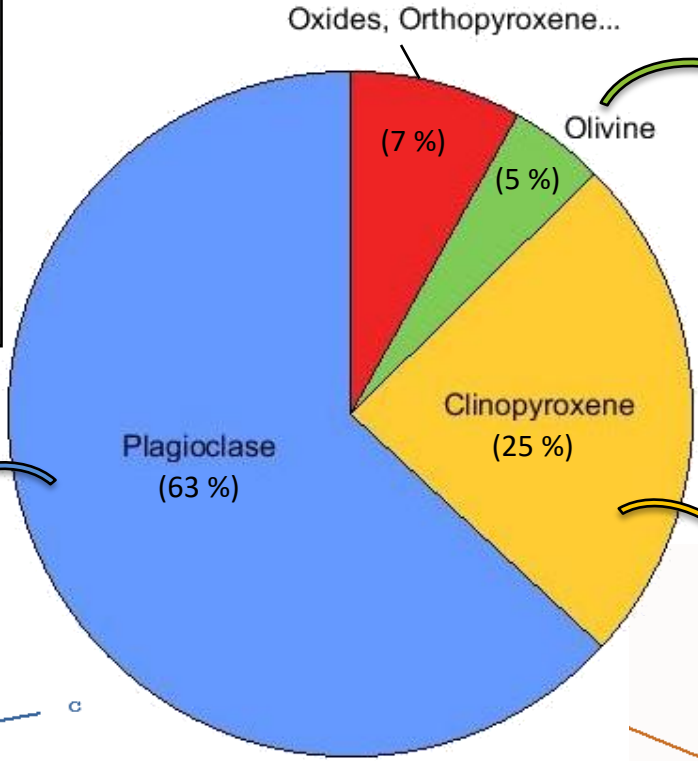


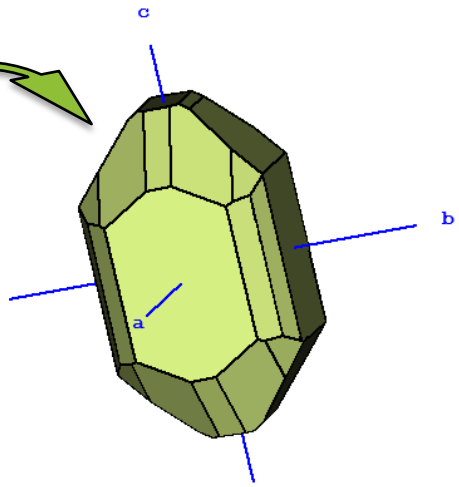
Studied rocks: olivine gabbros



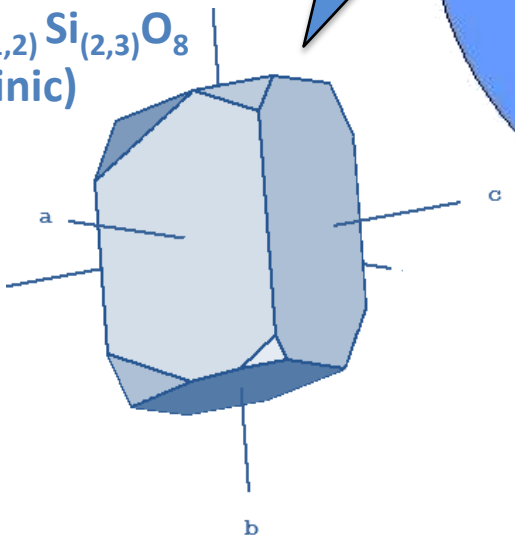
Microphotograph of an olivine-gabbro

Olivine
$(Mg,Fe)_2 SiO_4$
(orthorhombic)

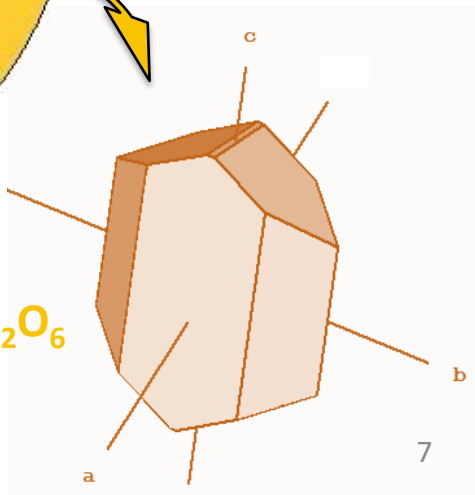




Plagioclase
$(Na,Ca)Al_{(1,2)} Si_{(2,3)}O_8$
(triclinic)



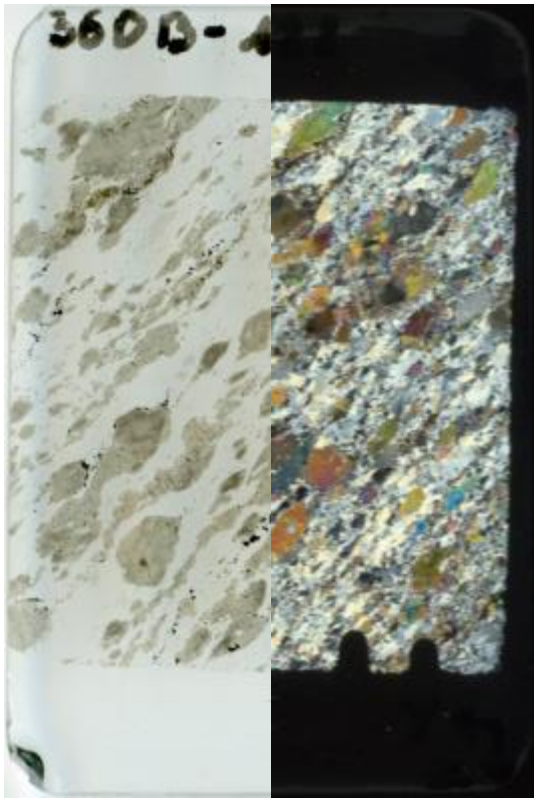
Clinopyroxene
$(Ca,Mg,Fe,Ti,Al)_2 (Si,Al)_2O_6$
(monoclinic)



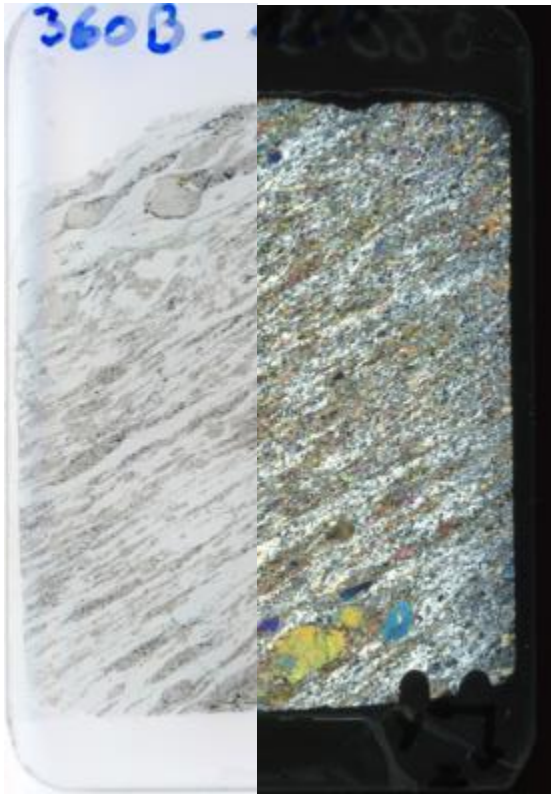
Microstructural observations

Magmatic subophitic texture

Protomylonitic texture



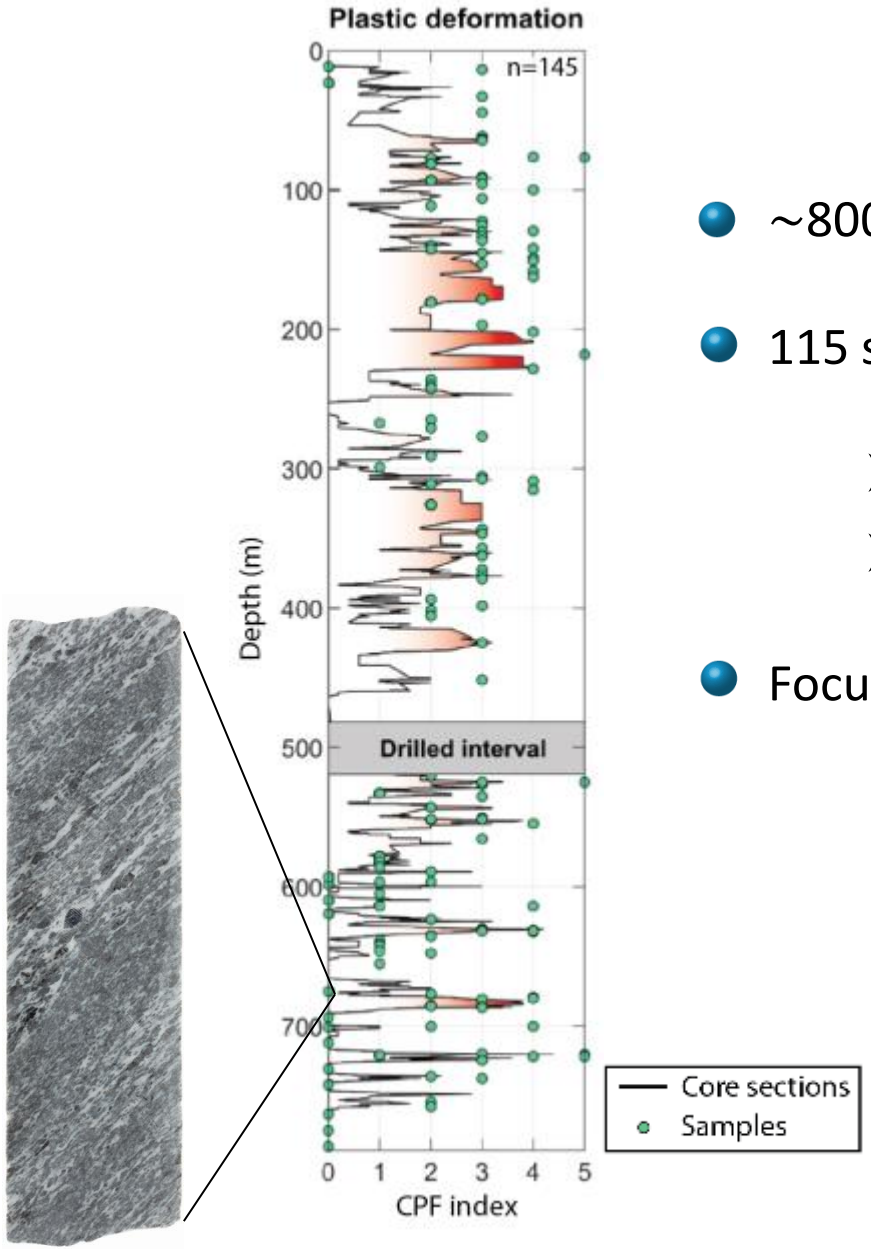
Ultramylonitic texture



0 3 5

Deformation intensity / Index of fabric

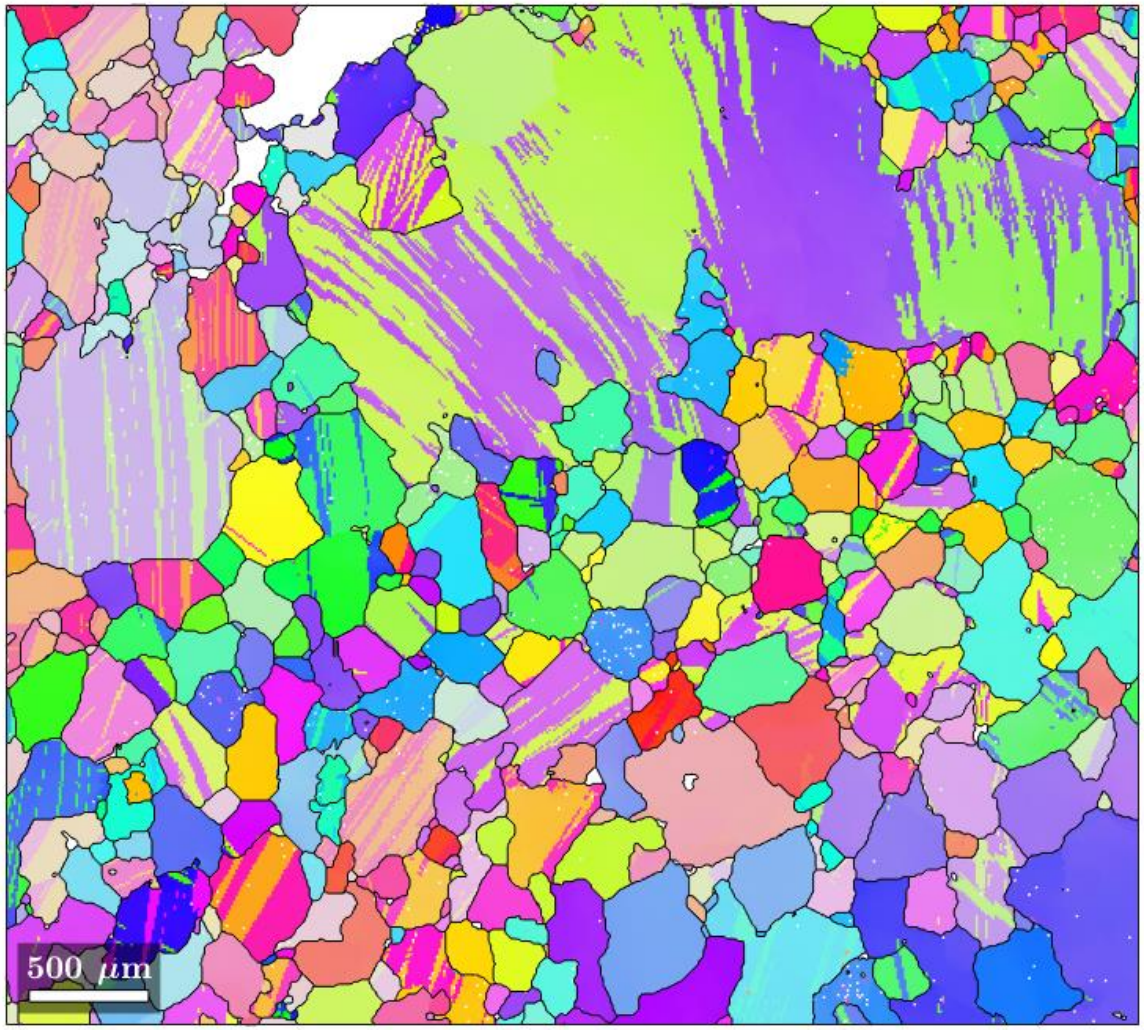
Microstructural observations



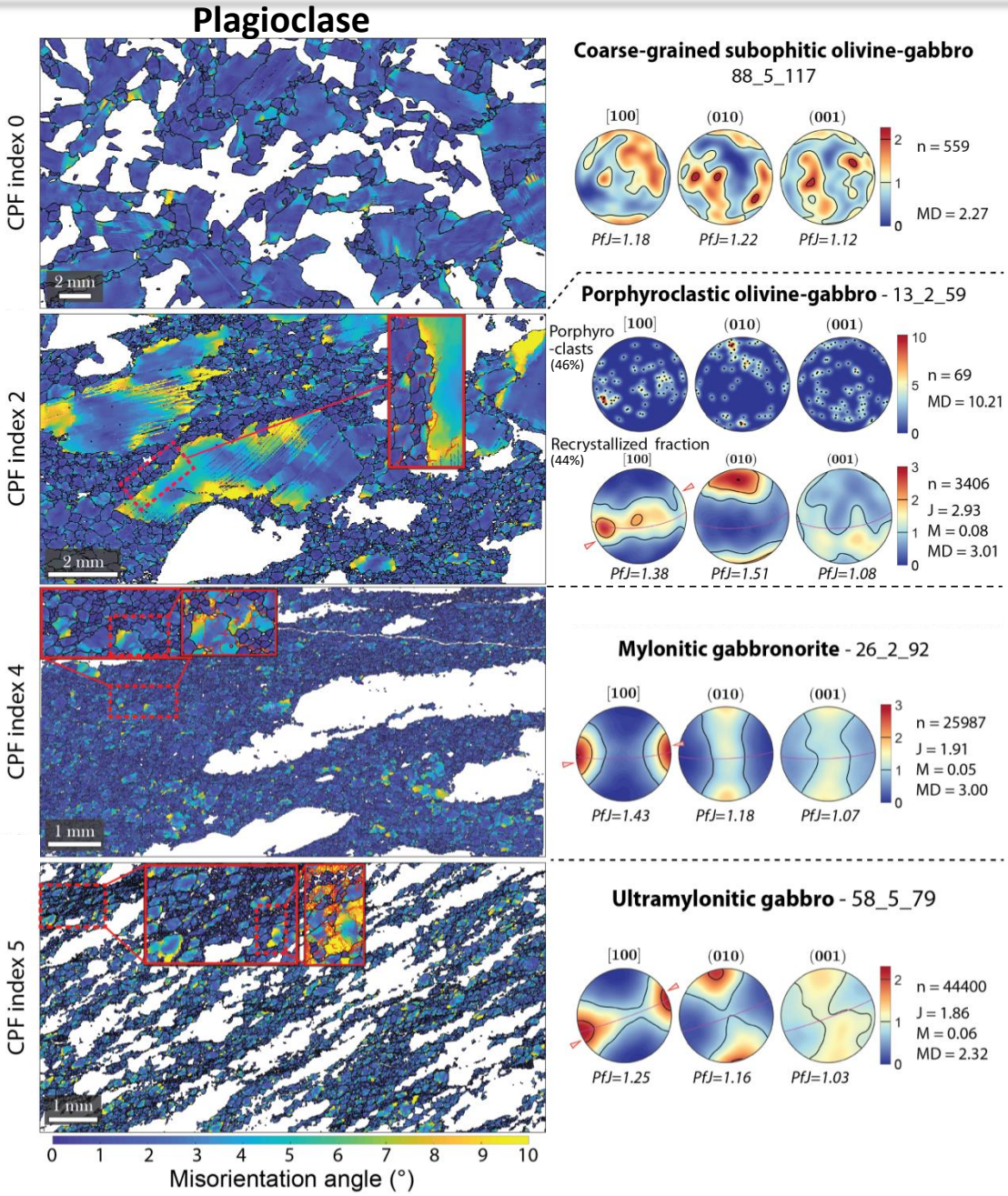
- ~800 m of gabbroic rocks
- 115 samples analyzed at the EBSD
  - Variably deformed textures
  - Similar mineralogic assemblage
- Focus on plagioclase (~60% of rock's volume)

Crystal-plastic fabric (CPF) intensity along the depth in Hole U1473A *(Dick et al., 2017)*

EBSD
analyses



EBSD - CPO



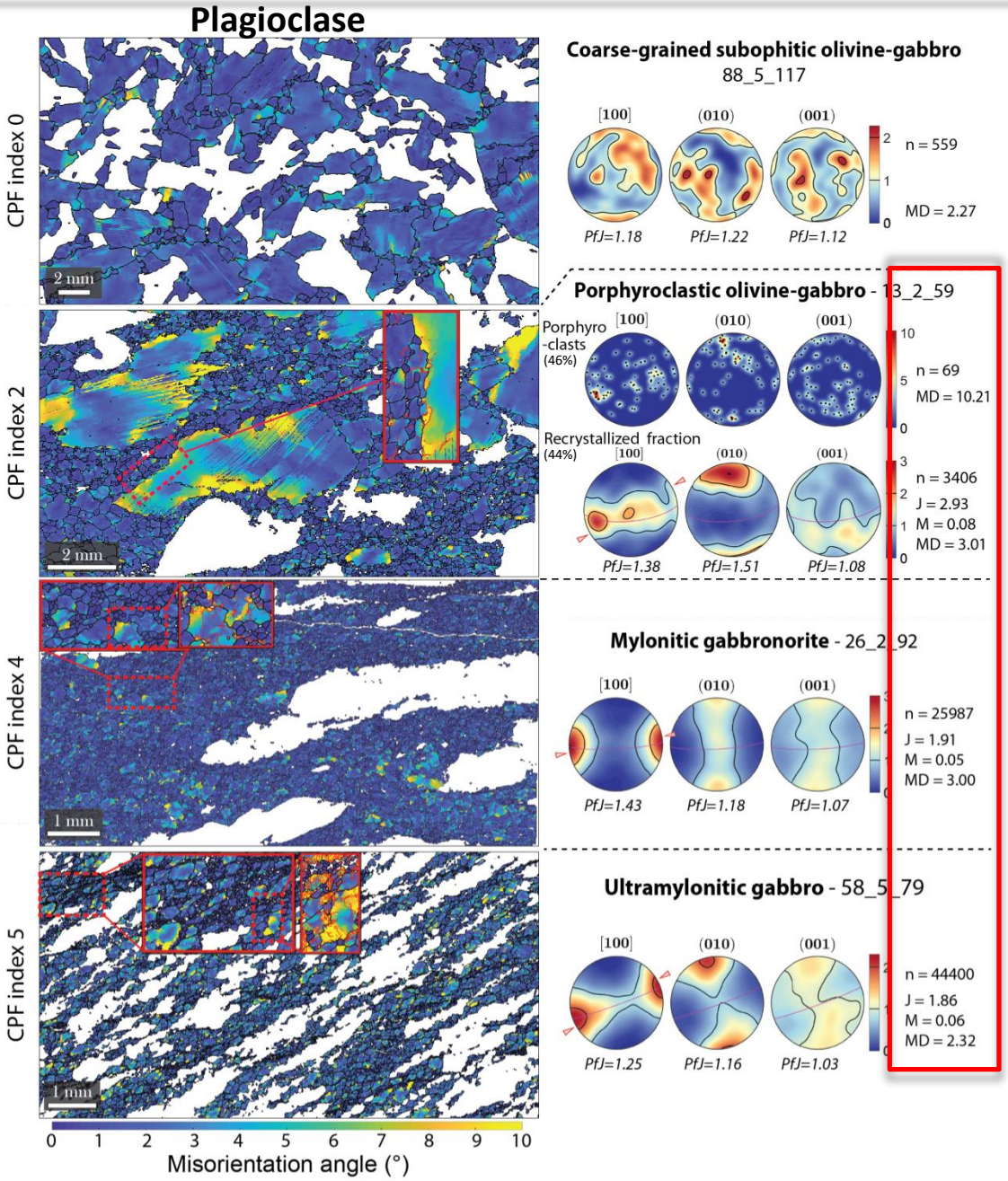
- CPO patterns in deformed samples

⇩

[100](010) slip system

Maps of misorientation from grain average orientation (mis2mean) and associated pole figures (PF, one point per grain, lower hemisphere, equal-area projection). *Insets presents subgrain boundaries in red. Pink great circles in PF are plagioclase (010), nearly parallel to the trace of the foliation (red arrows around [100]pole figure). "n", number of grains; "J", J index; "M", M index; "MD", maximum density in the PF; "PfJ", J index calculated for single PF.*

EBSD - CPO



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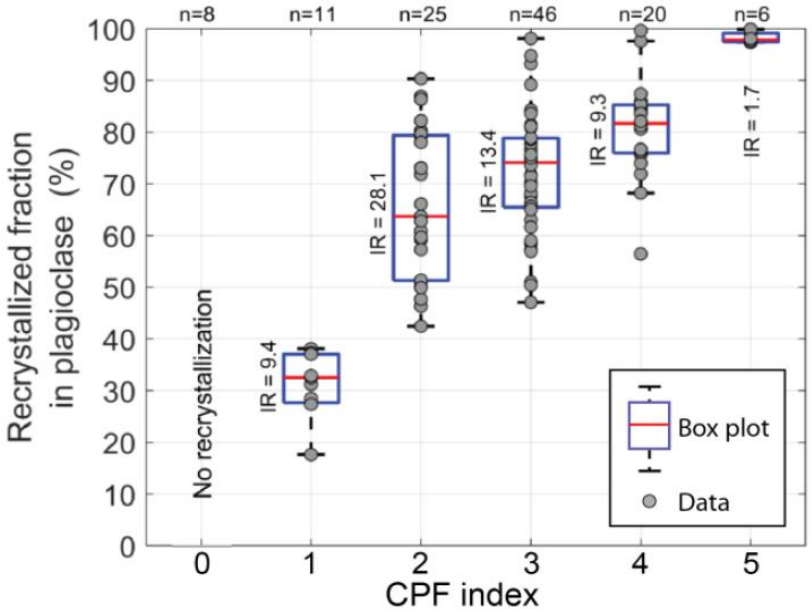
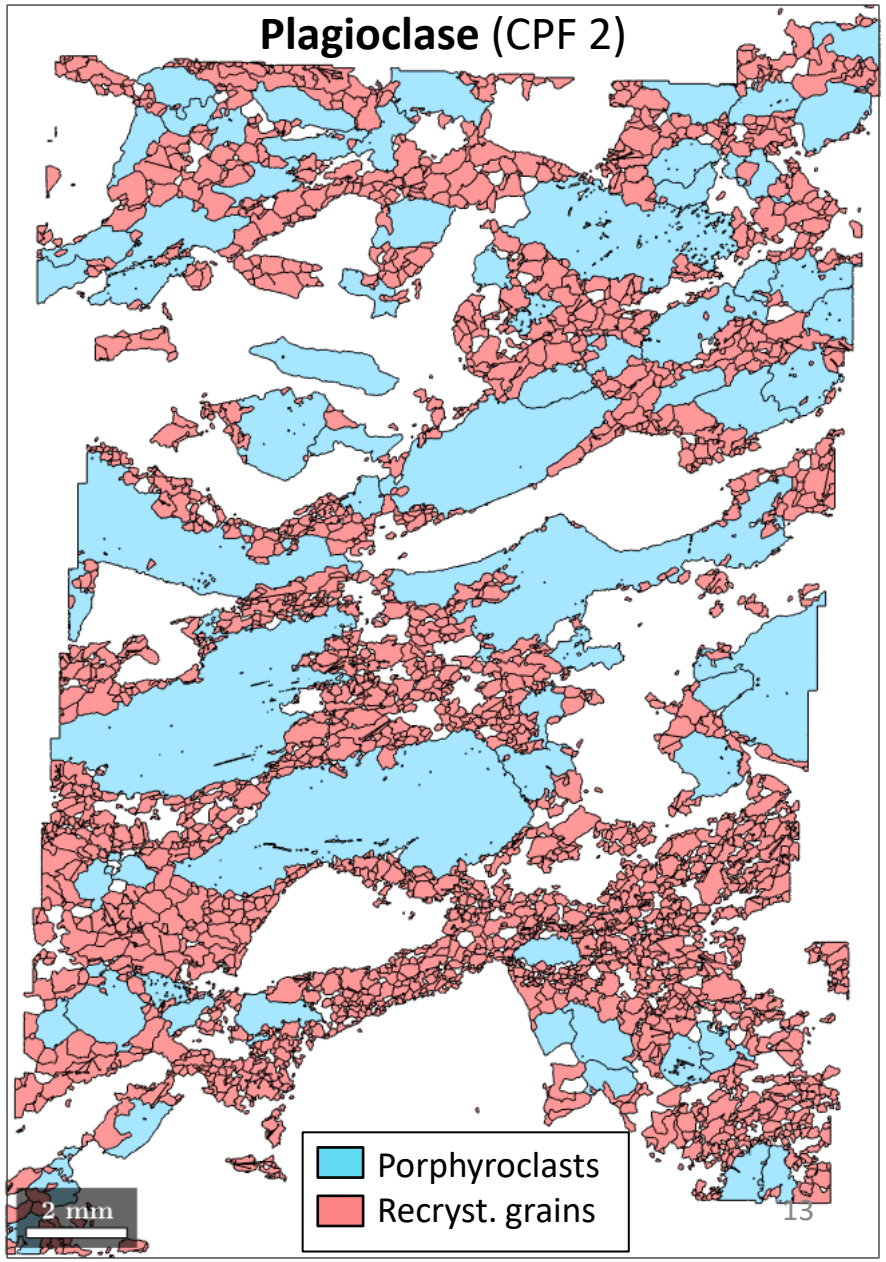
EBSD - Recrystallization

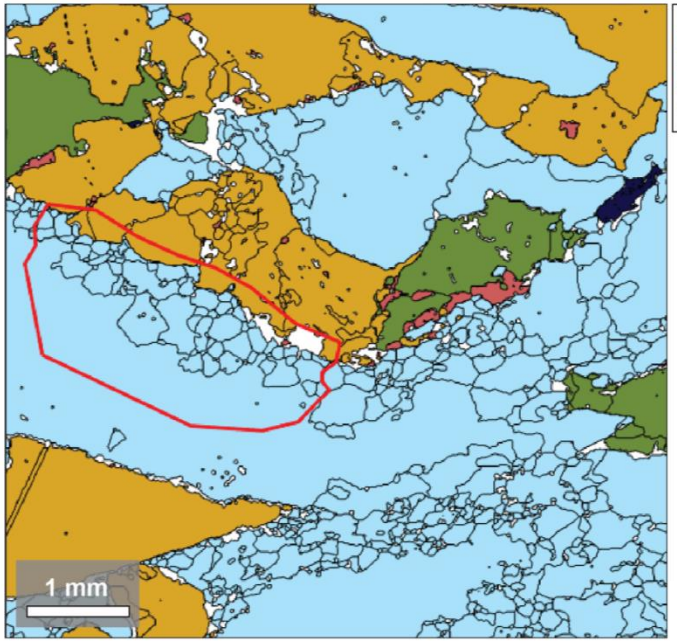
Automatic selection of grains

- Parameters used:
  - Grain average KAM (< 0.6°)
  - Boundary irregularity (convexity < 1.4)
  - Equivalent diameter (< 700µm)

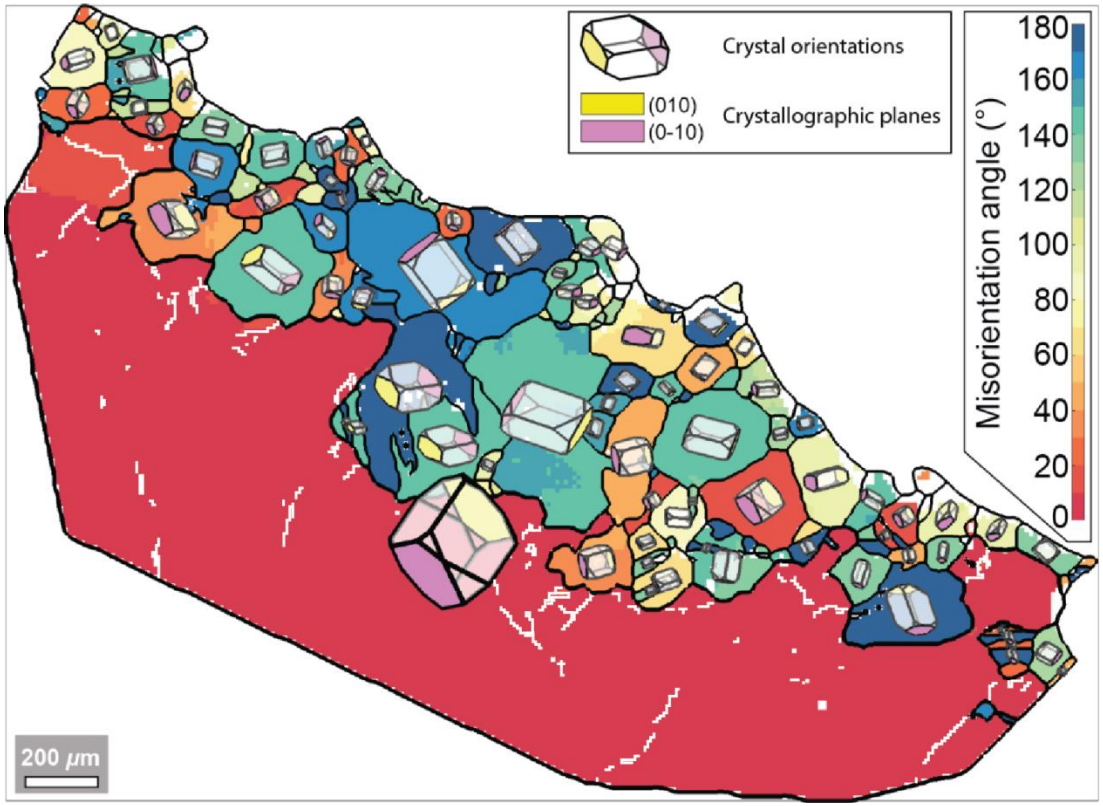




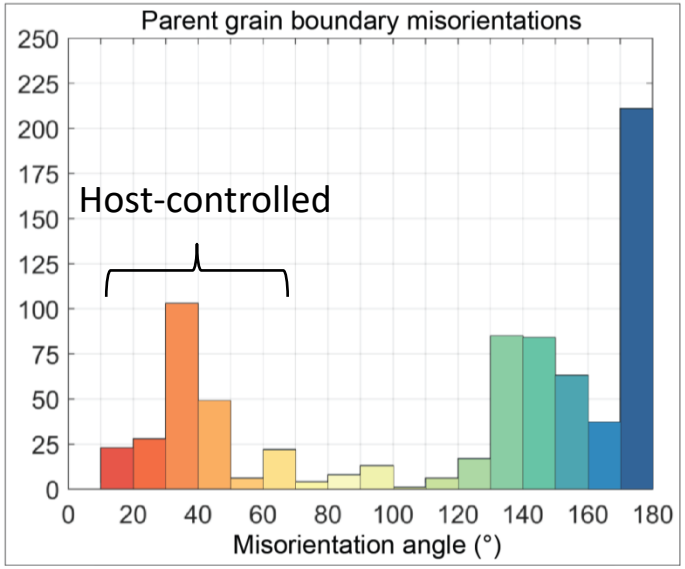
EBSD - Recrystallization



Phase map with location of the subset.



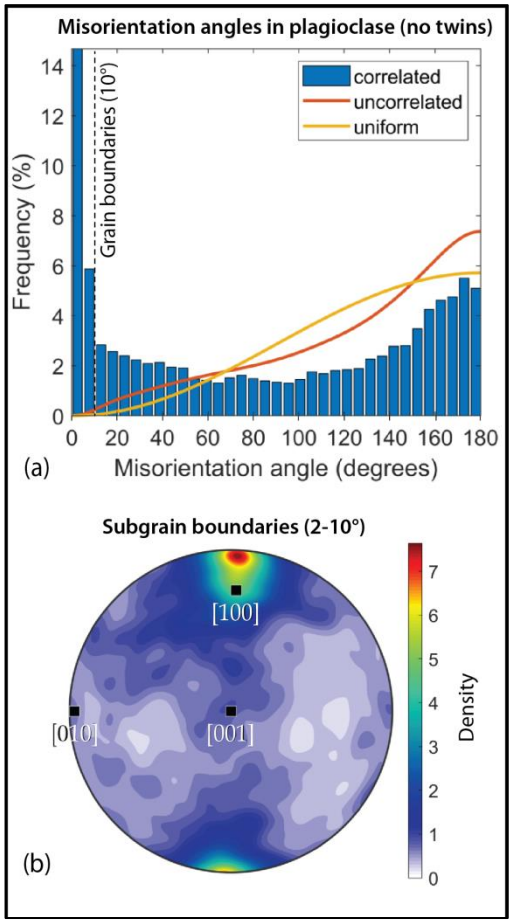
Orientation difference between a parent grain and its recrystallized mantle in plagioclase. *Porphyroclast subgrain boundaries are indicated in white.*



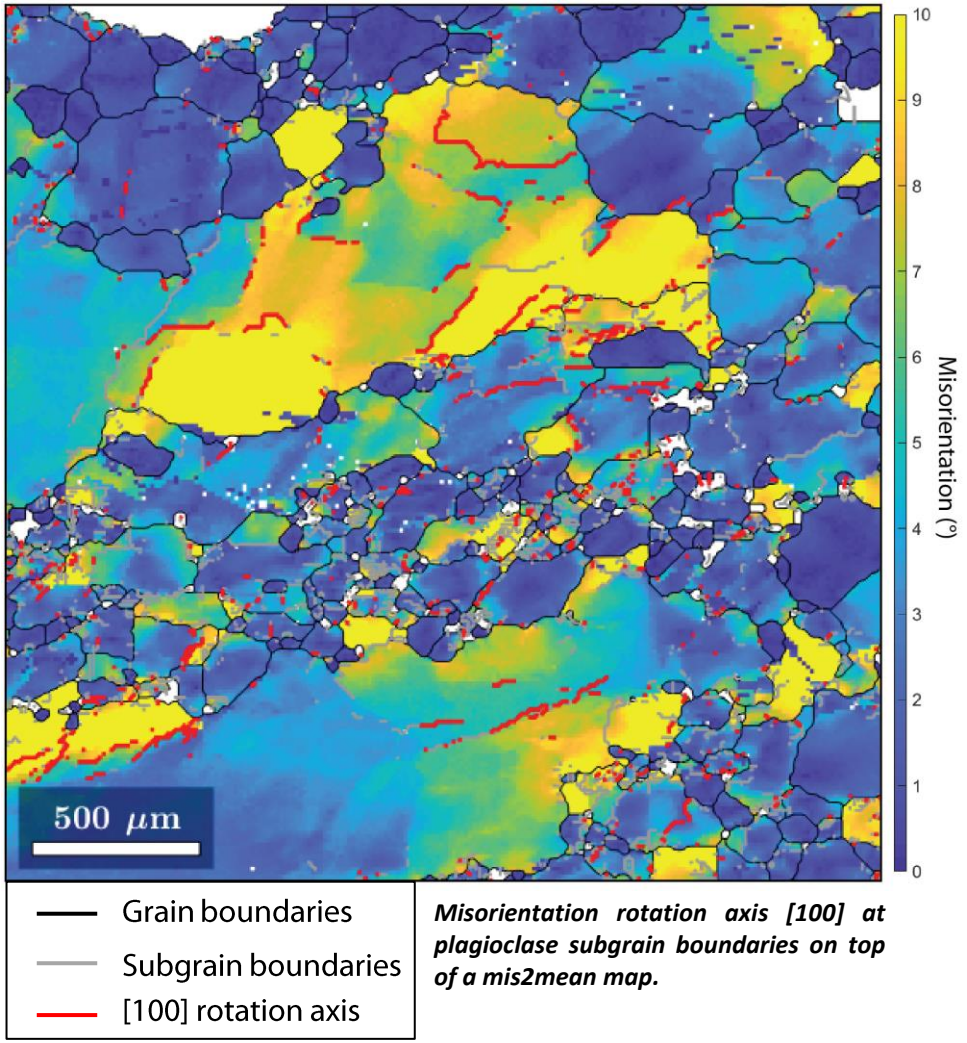
Histogram of misorientations at parent grain boundary.

Progressive Subgrain Rotation recrystallization (**SGR**)

EBSD - Recrystallization & Misorientations

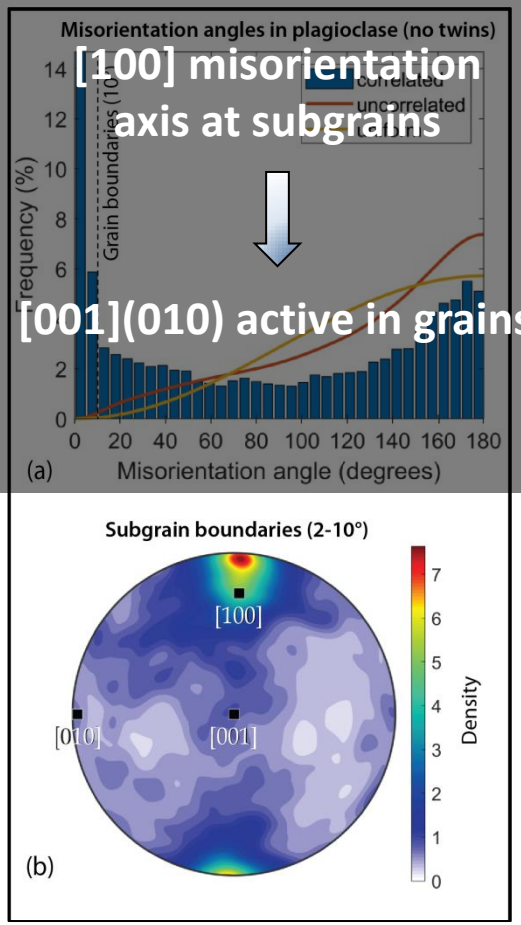


Representative misorientations characteristics in plagioclase. *(a) Misorientation angle distribution histogram, all grains are considered. (b) inverse pole Figures (IPF, antipodal, equal area projection) showing the misorientation axes distributions at subgrain boundaries.*



Misorientation rotation axis [100] at plagioclase subgrain boundaries on top of a mis2mean map.

EBSD - Recrystallization & Misorientations



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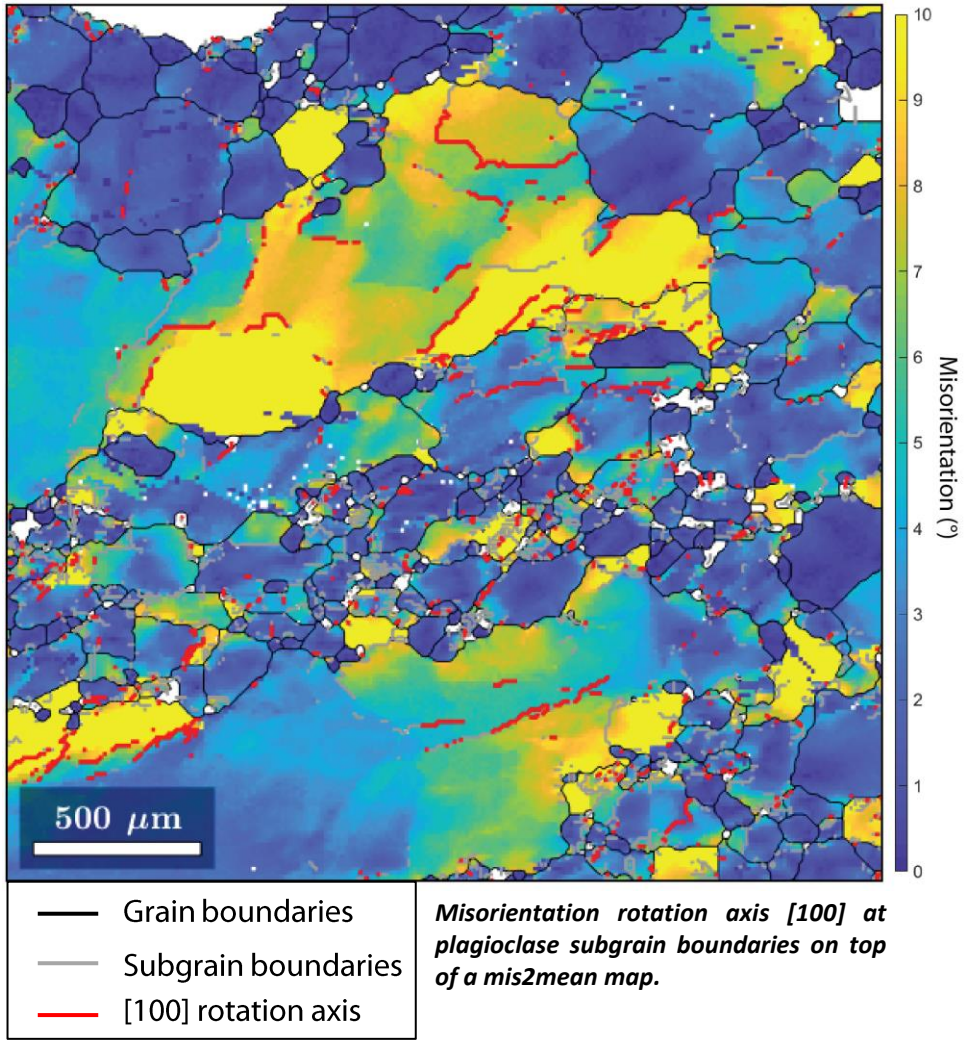


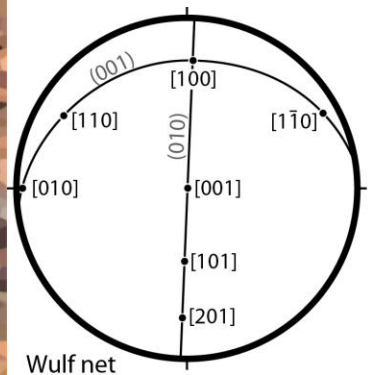
Misorientation rotation axis [100] at plagioclase subgrain boundaries on top of a mis2mean map.

EBSD - Misorientations & slip systems

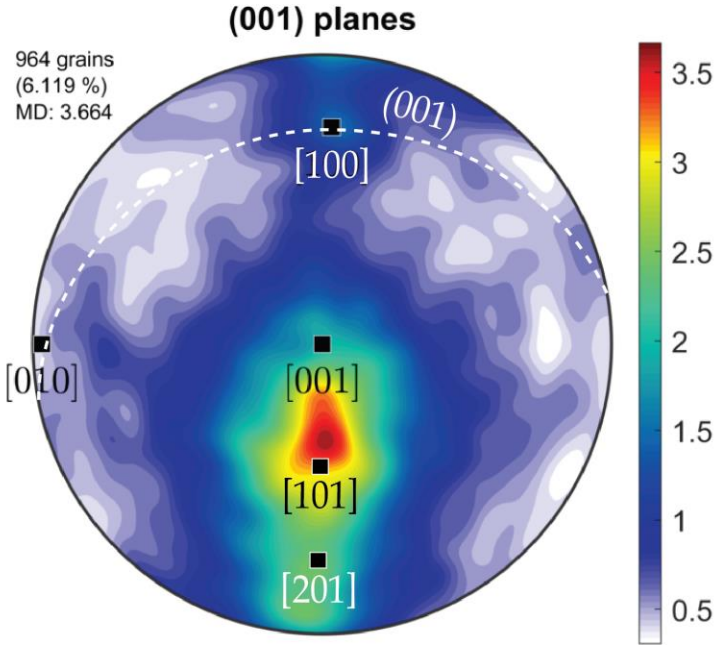
- Grain selection (2 groups):
  (001) & (010) planes parallel to the analyzed plane.
- Slip systems:

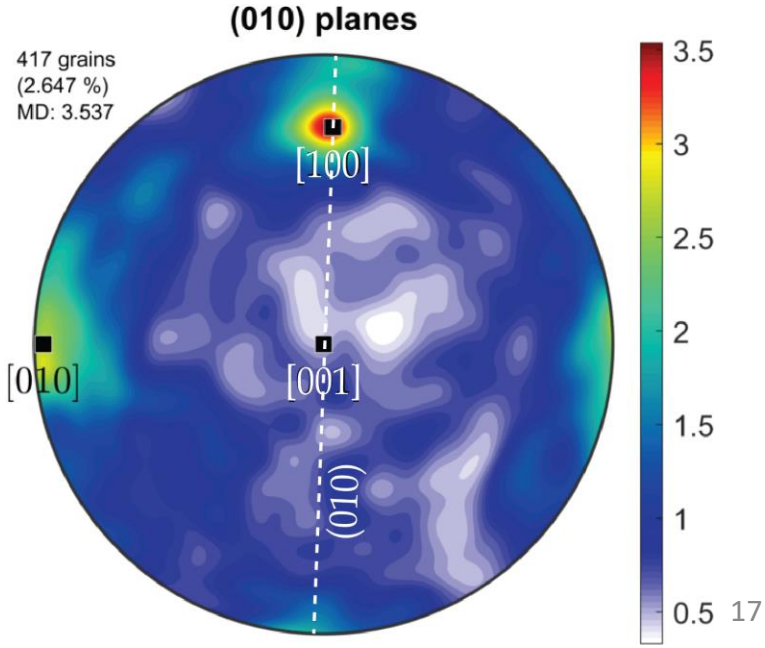
  -> <u>in (001):</u> [100](001) ; ½[110](001) ; ½[1$\bar{1}$0](001)

  -> <u>in (010):</u> [100](010) ; [001](010)



Wulf net
Antipodal





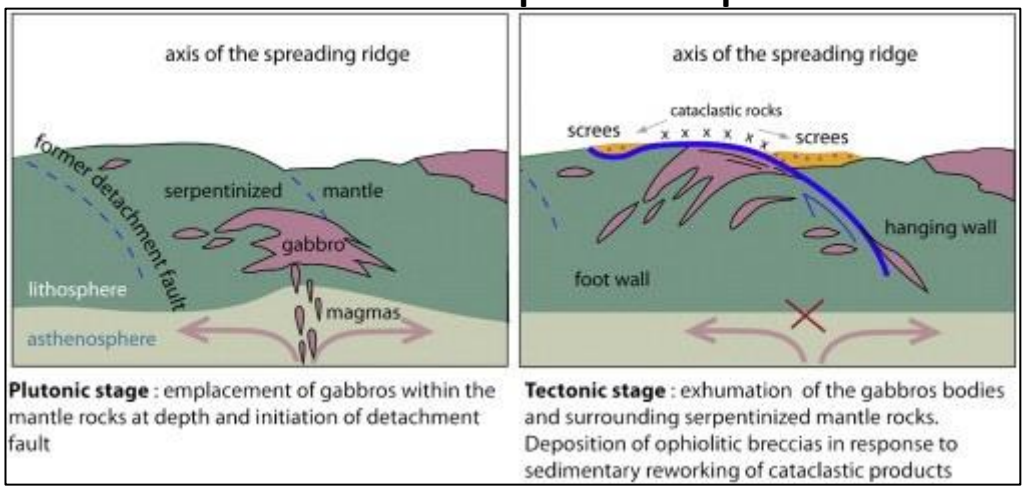
Conclusion

- **Identified slip systems:**
  - Dislocation creep active from ~900°C to 700-600°C

Slip systems	[100](010)	[001](010)	[100](001)	½[110](001)	½[1$\bar{1}$0](001)
T (°C)	> 900 - ~ 600	800 - 600	750 - ~ 600	700 - 650	700 - ~ 600

Decreasing temperature

Oceanic Core Complex development



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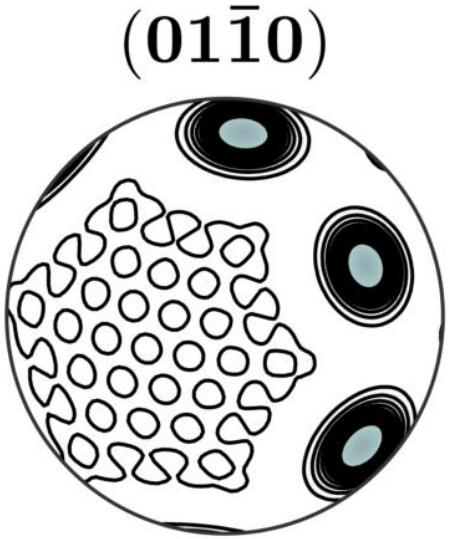
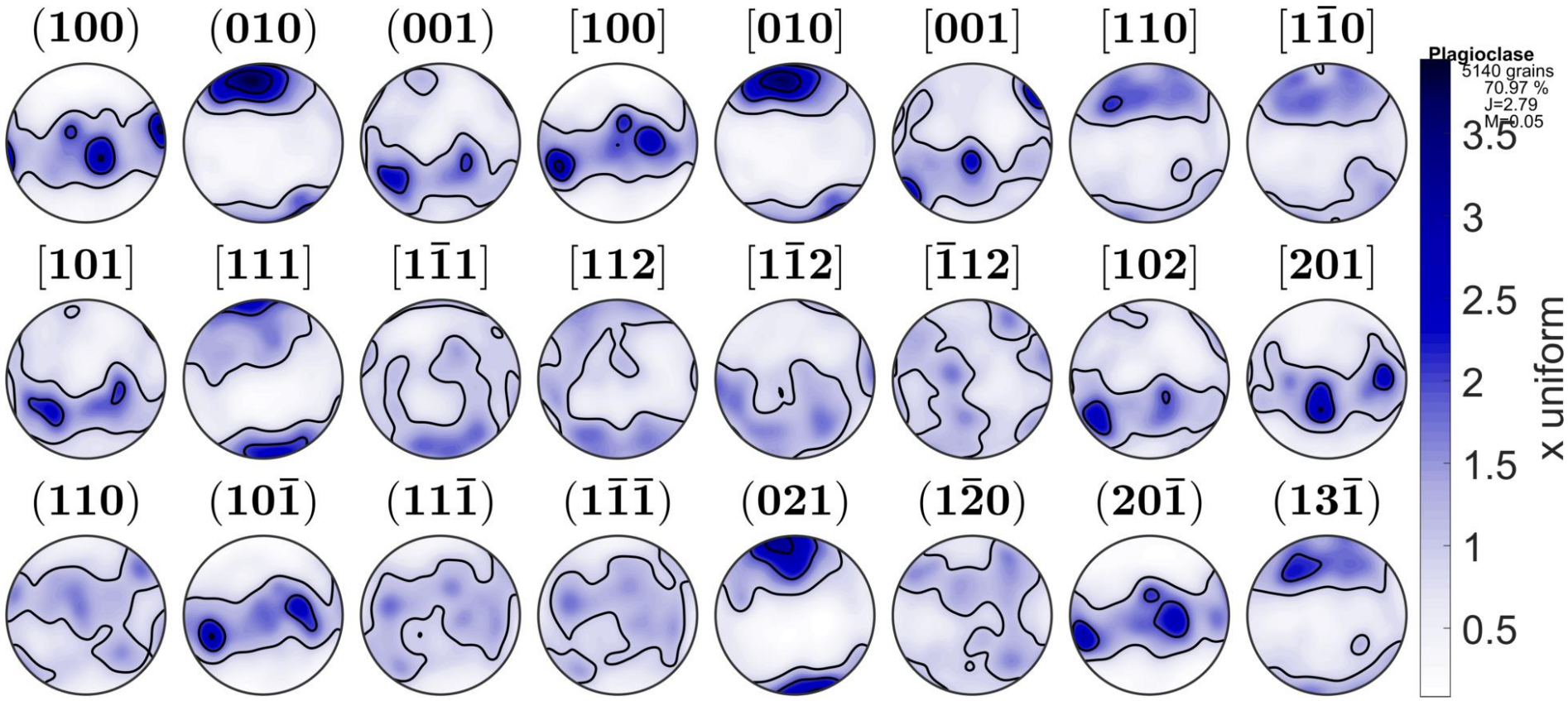
Tectonic stage : exhumation of the gabbros bodies and surrounding serpentinized mantle rocks. Deposition of ophiolitic breccias in response to sedimentary reworking of cataclastic products

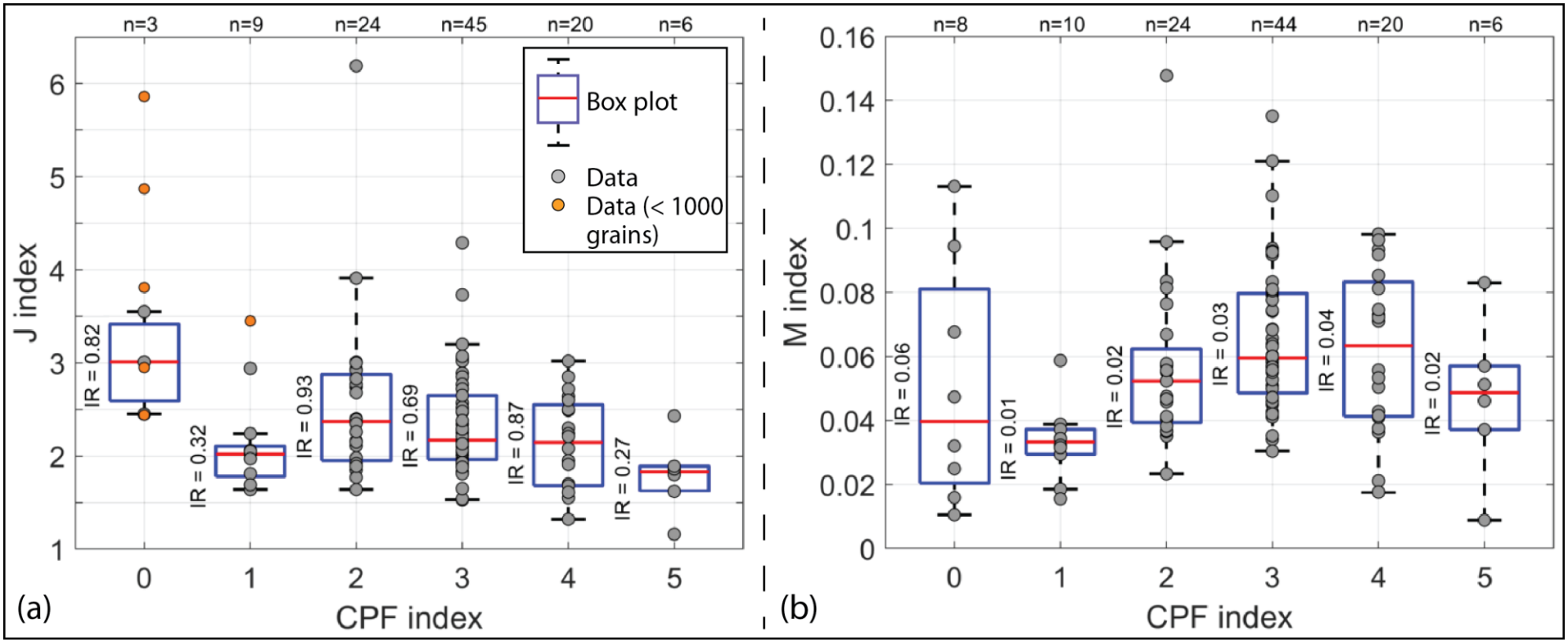
Cartoons depicting the evolution of the Tethyan oceanic basement using the model of OCC development *(Lagabrielle et al., 2015)*

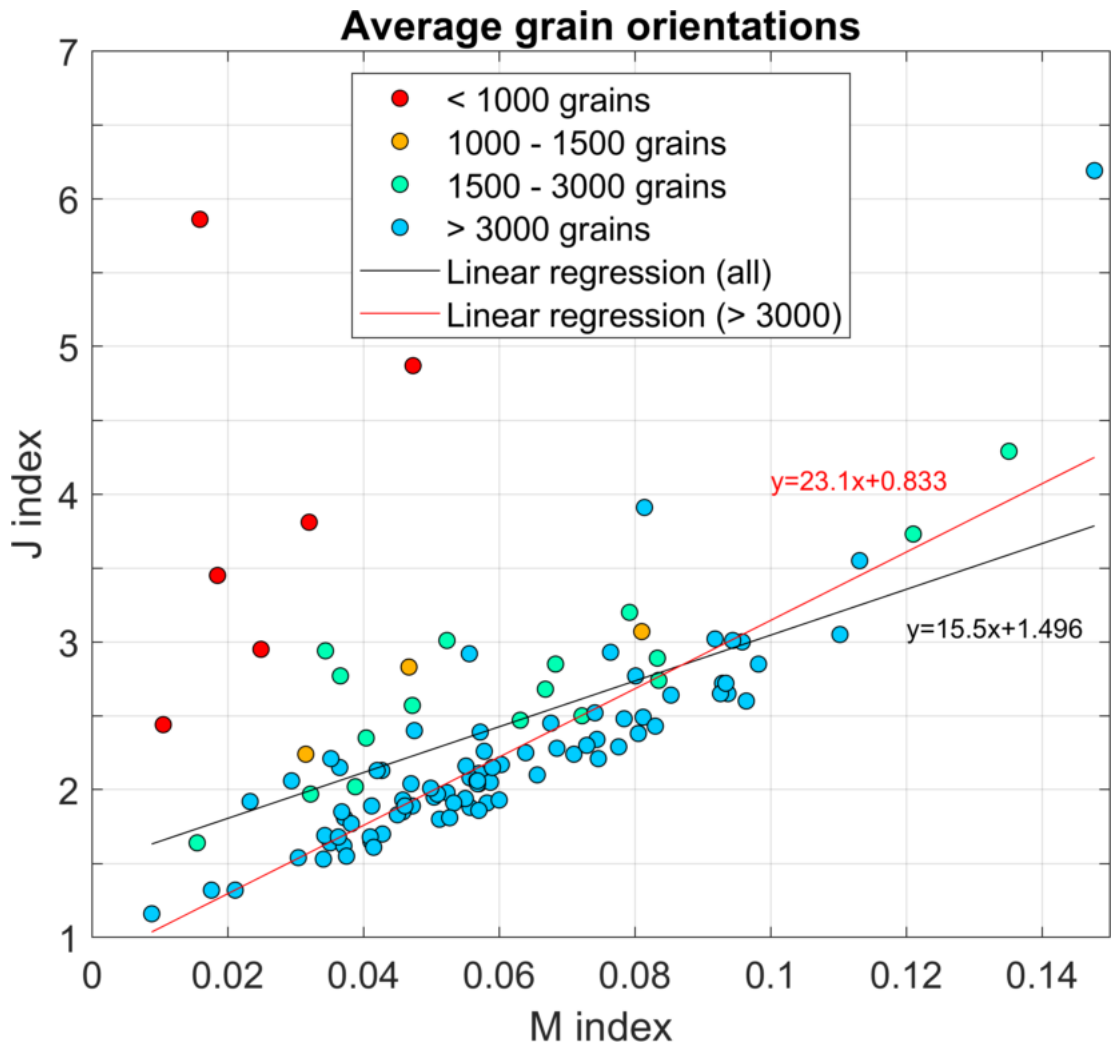
Thank you

Christmas balls ornaments in ilmenite pole figures




(100)
(010)
(001)
[100]
[010]
[001]
[110]
[1$\bar{1}$0]
[101]
[111]
[1$\bar{1}$1]
[112]
[1$\bar{1}$2]
[$\bar{1}$12]
[102]
[201]
(110)
(10$\bar{1}$)
(11$\bar{1}$)
(1$\bar{1}\bar{1}$)
(021)
(1$\bar{2}$0)
(20$\bar{1}$)
(13$\bar{1}$)
Plagioclase
5140 grains
70.97 %
J=2.79
M=0.05
3.5
3
2.5
2
1.5
1
0.5
x uniform


n=3
n=9
n=24
n=45
n=20
n=6
Box plot
Data
Data (< 1000 grains)
J index
IR = 0.82
IR = 0.32
IR = 0.93
IR = 0.69
IR = 0.87
IR = 0.27
CPF index
(a)
n=8
n=10
n=24
n=44
n=20
n=6
M index
IR = 0.06
IR = 0.01
IR = 0.02
IR = 0.03
IR = 0.04
IR = 0.02
CPF index
(b)


Average grain orientations
< 1000 grains
1000 - 1500 grains
1500 - 3000 grains
> 3000 grains
Linear regression (all)
Linear regression (> 3000)
y=23.1x+0.833
y=15.5x+1.496
J index
M index
1
2
3
4
5
6
7
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14