Quantitative characterisation of mollusc shell textures

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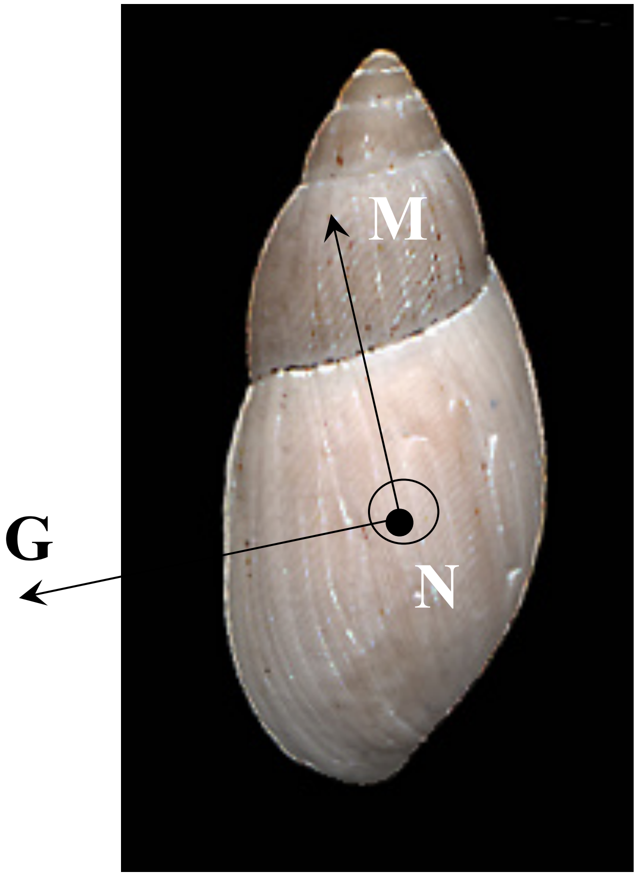
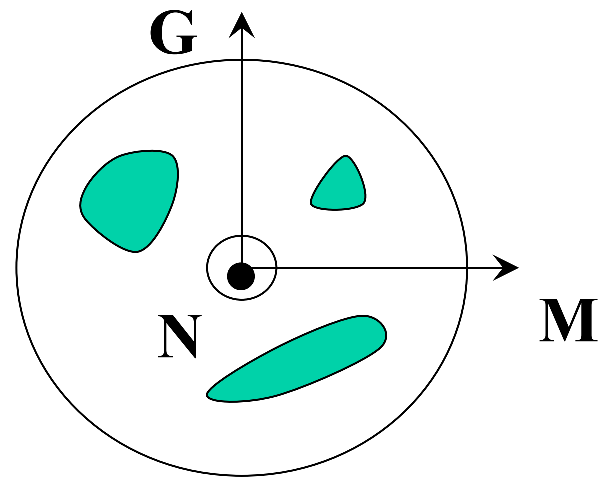
Summary

- Reference frames and experiments
- Typical results with x-rays and electrons
- **c**- and **a**-axes texture patterns
- Twinning in nacre
- Texture terms and nomenclature
- Microstructure versus texture
- Interest in phylogeny: example of nacre

Reference frame



- Crystal: $CaCO_3$, aragonite (Pmcn) or calcite ($R\bar{3}c$)
- Sample: triclinic (WIMV)



X-rays experiments

- **Point detector**: λ_{Fe} $K\overline{\alpha}$, 4 Huber circles (DGG Berkeley)

  ⇨ 4 pole figures, overlaps refined in OD

  Arag: {111/021} + {012/121} + {102/200} + {221}

  Calc: {012} + {104/006} + {110} + {113}

- **INEL CPS 120**: λ_{Cu} $K\overline{\alpha}$, 4 Huber circles, (LPEC Le Mans)

  ⇨ 8 or 9 pole figures, partial deconvolution of overlaps

  Arag: … + {112/031} + {202/041} + {132/212} + {113/023}

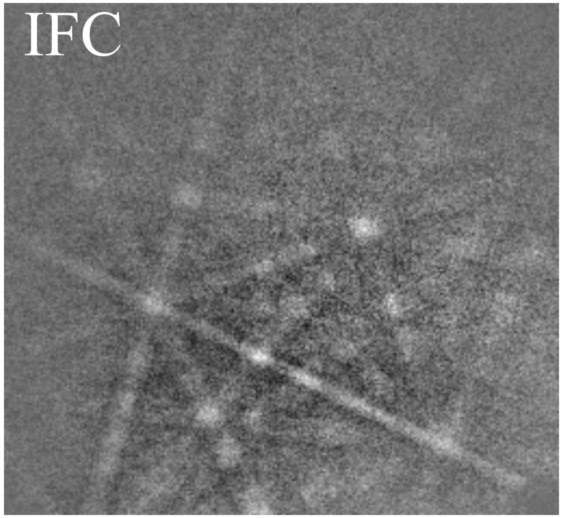
  Calc: … + {202} + {024/018/116} + {211/122/10$\underline{10}$} + {125} + {300/00$\underline{12}$}

EBSD experiments

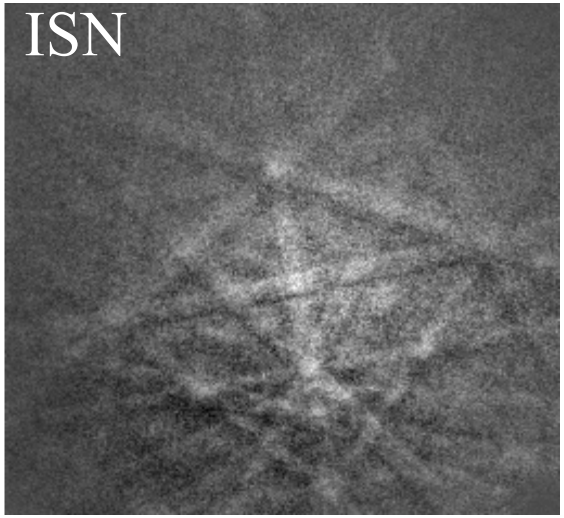
Leo microscope + Berkeley system (DGG Berkeley)

⇨ Only smoothest, large grained calcite and aragonite layers

Crassostrea gigas

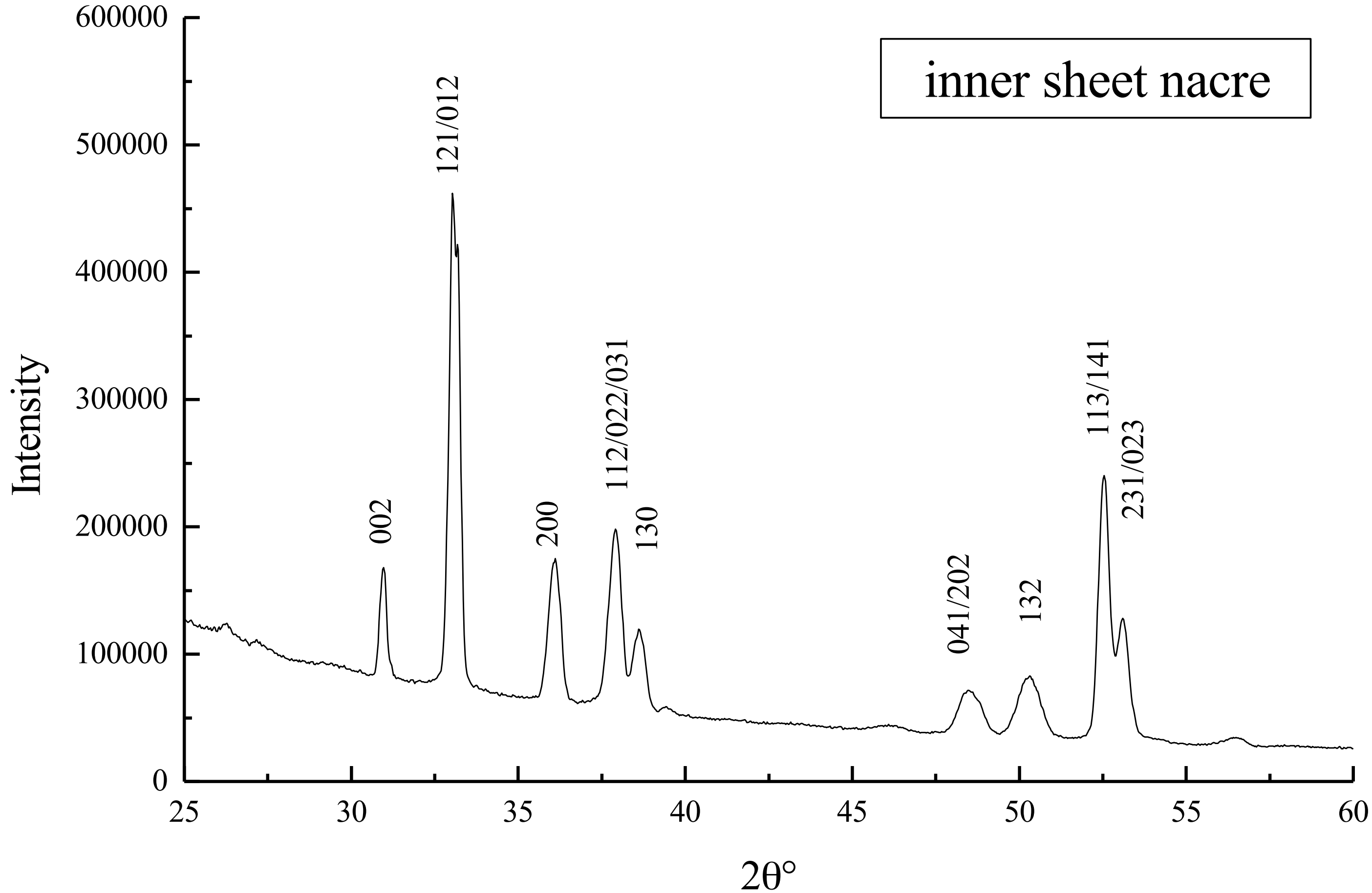


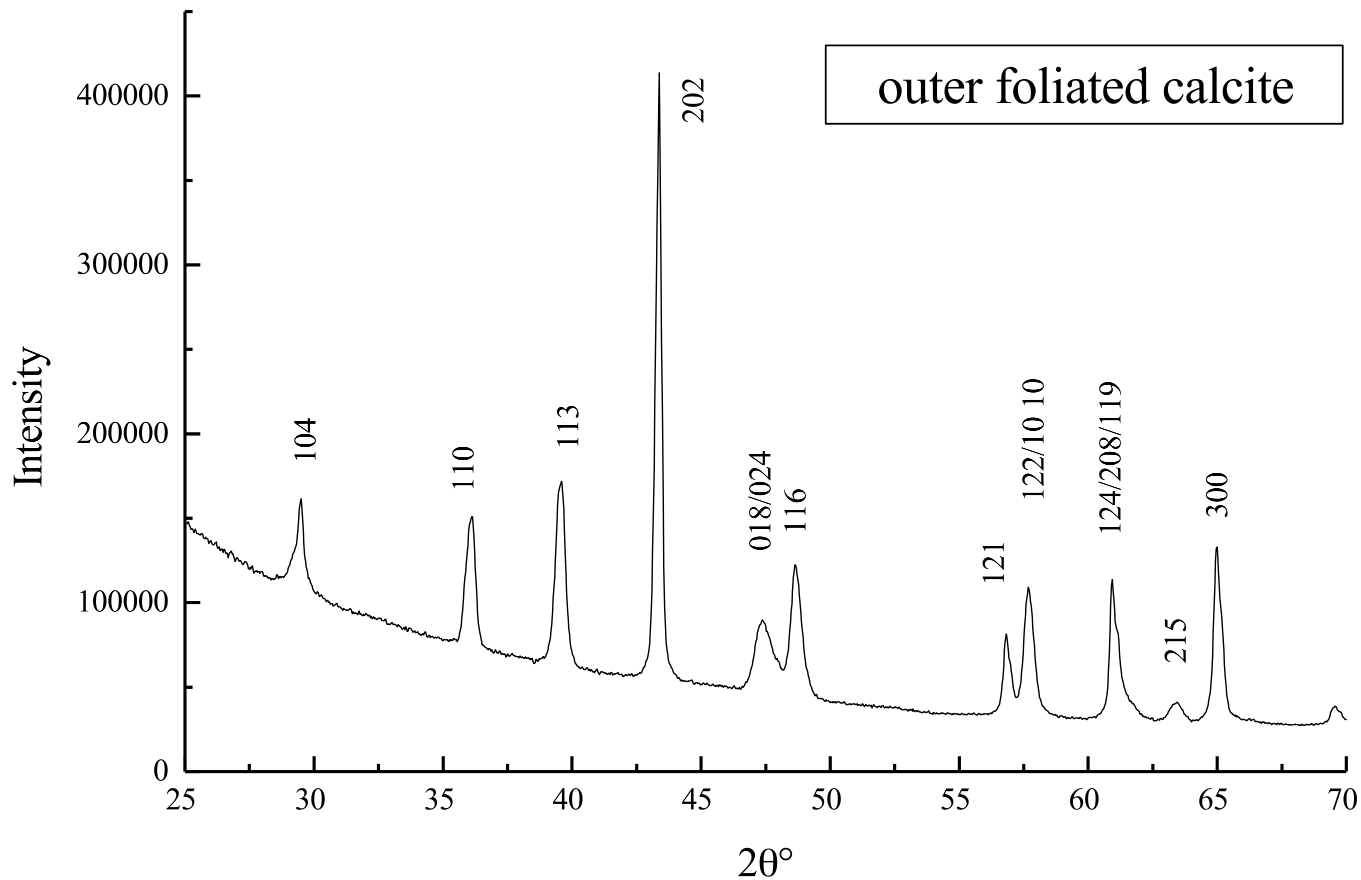
Pteria penguin



Typical x-ray diffraction pattern

Mytilus edulis (common mussel): sum diagrams

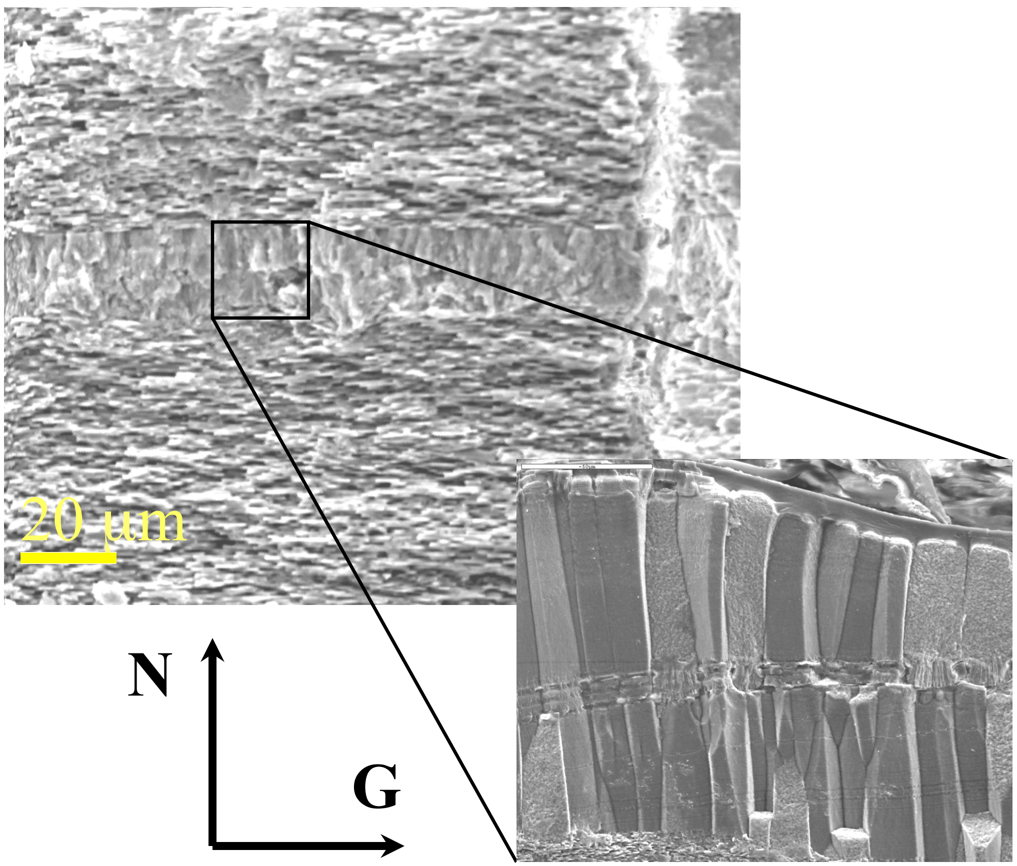


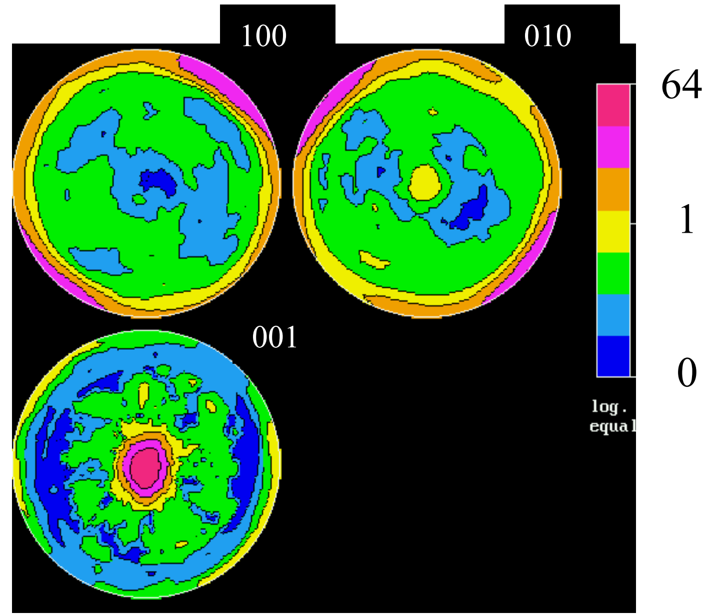


outer foliated calcite
Intensity
2θ°
0
100000
200000
300000
400000
25
30
35
40
45
50
55
60
65
70
104
110
113
202
018/024
116
121
122/10 10
124/208/119
215
300

Microstructure versus texture

Inner sheet nacre of *Anodonta cygnea* (river mussel)

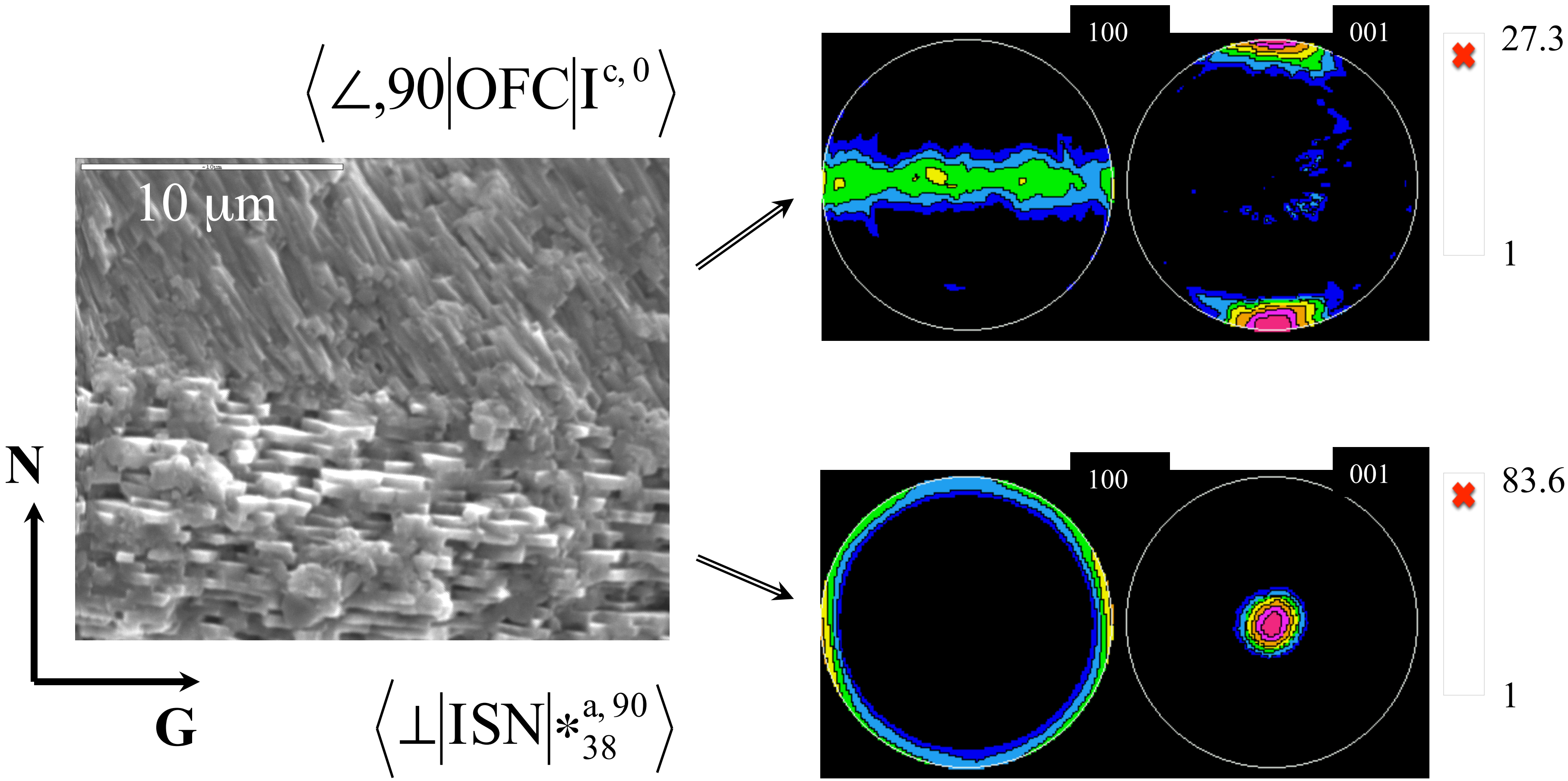




$$\left\langle \perp \middle| \mathrm{ISN} \middle| *^{a,\,-45}_{25} \right\rangle$$

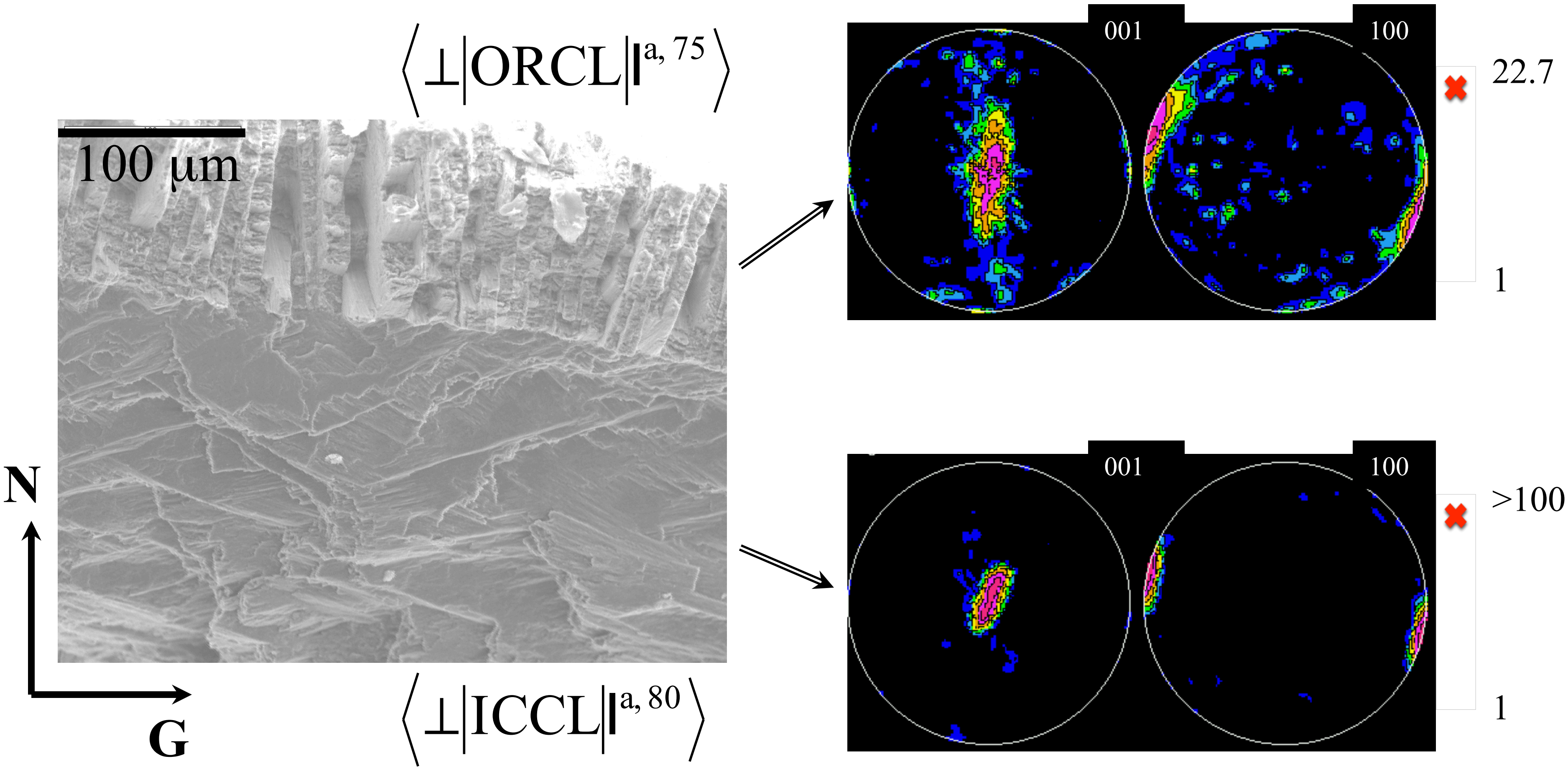
Microstructure versus texture

Bathymodiolus thermophilus (-2400m deep mussel)



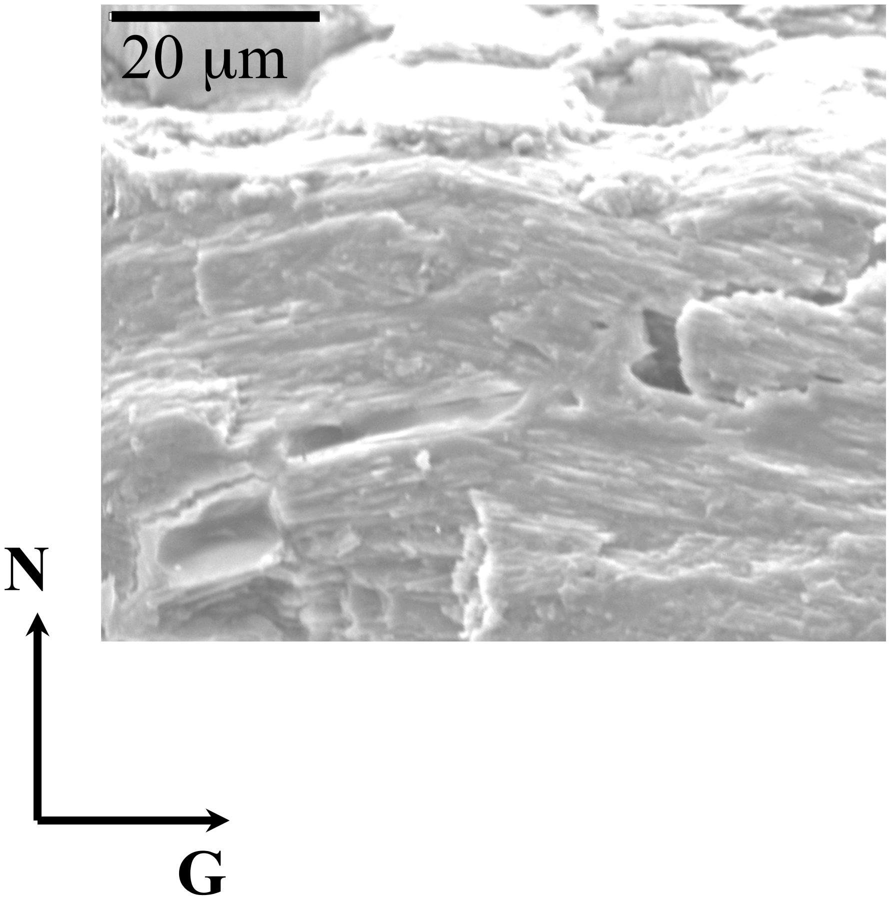
Microstructure versus texture

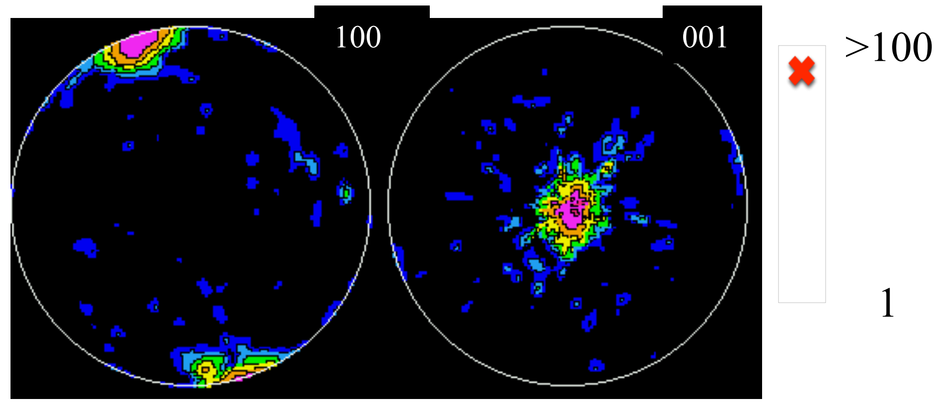
Euglandina sp.



Microstructure versus texture

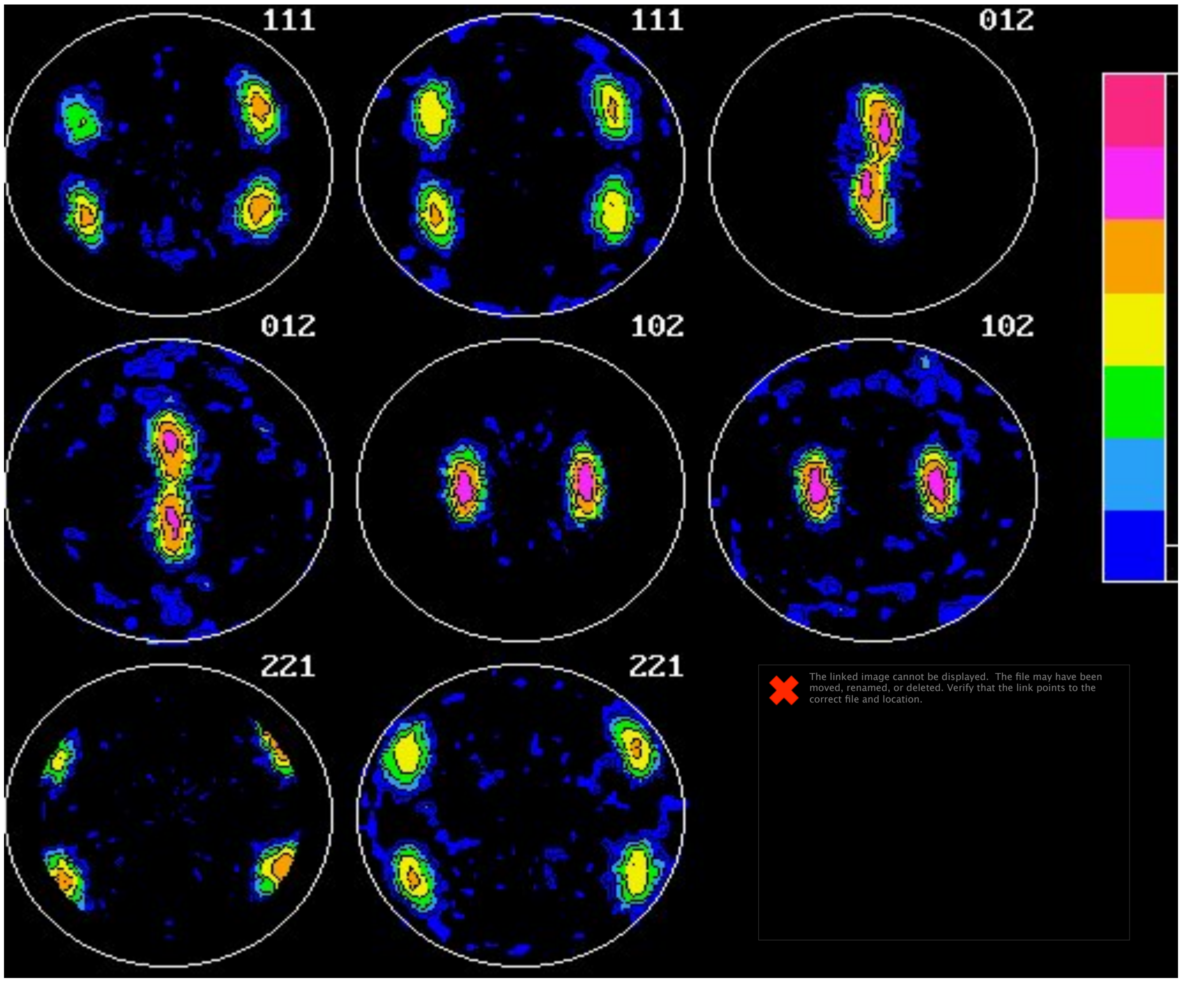
Cyclophorus woodianus





$$\left\langle \perp \middle| \mathrm{IRCL} \middle|^{a,\,20} \right\rangle$$

OD-reliability (x-rays: point detector): *Helix pomatia*
(Burgundy land snail: Outer com. crossed lamellar)



22.7

Lin. scale

Eq. area

1 m.r.d.

$RP_{0.05} = 67\%$

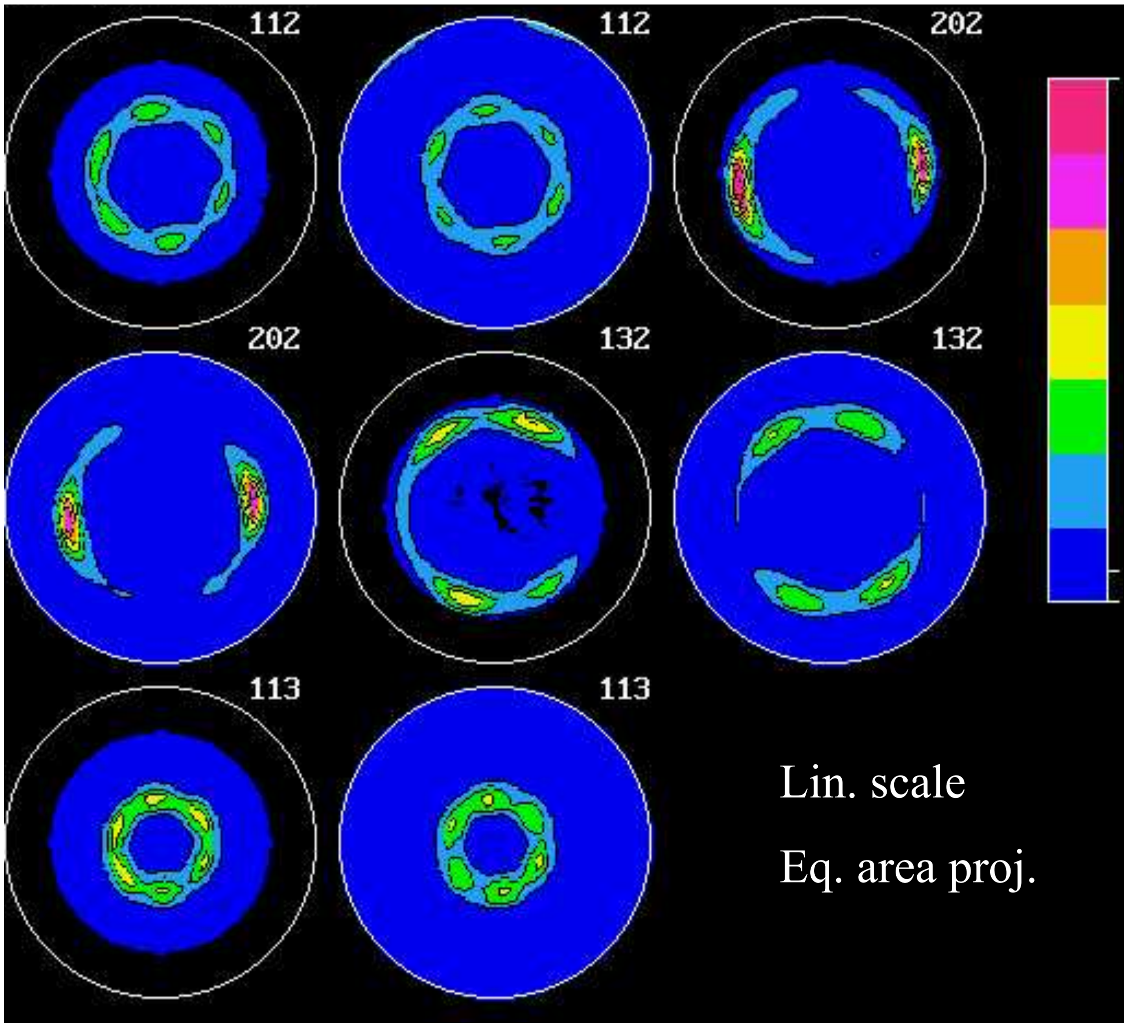
$RP_1 = 40\%$

$S = -4.1$

$F^2 = 106$ m.r.d.^{2}

$OD_{max} = 444$ m.r.d.

OD-reliability (x-rays: PSD): *Bathymodiolus thermophilus* (deep ocean mussel: Inner sheet nacre)



$RP_{0.05} = 65\%$

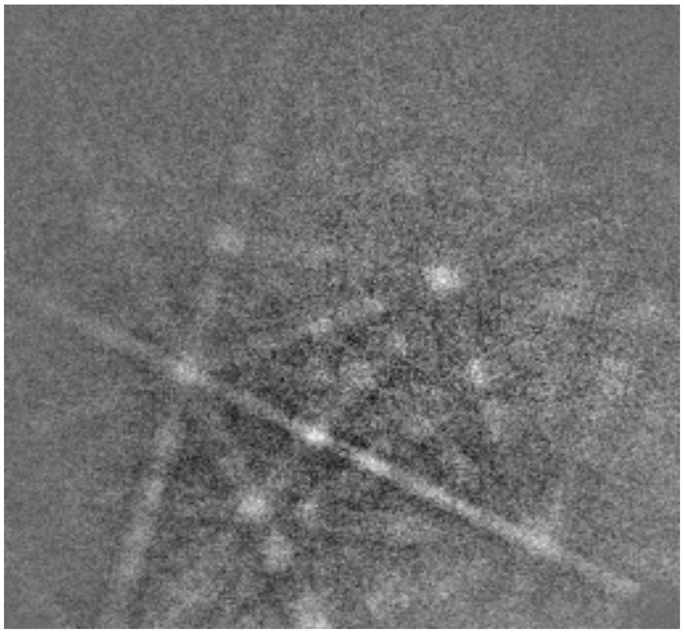
$RP_1 = 21\%$

$S = - 2.9$

$F^2 = 65$ m.r.d.^{2}

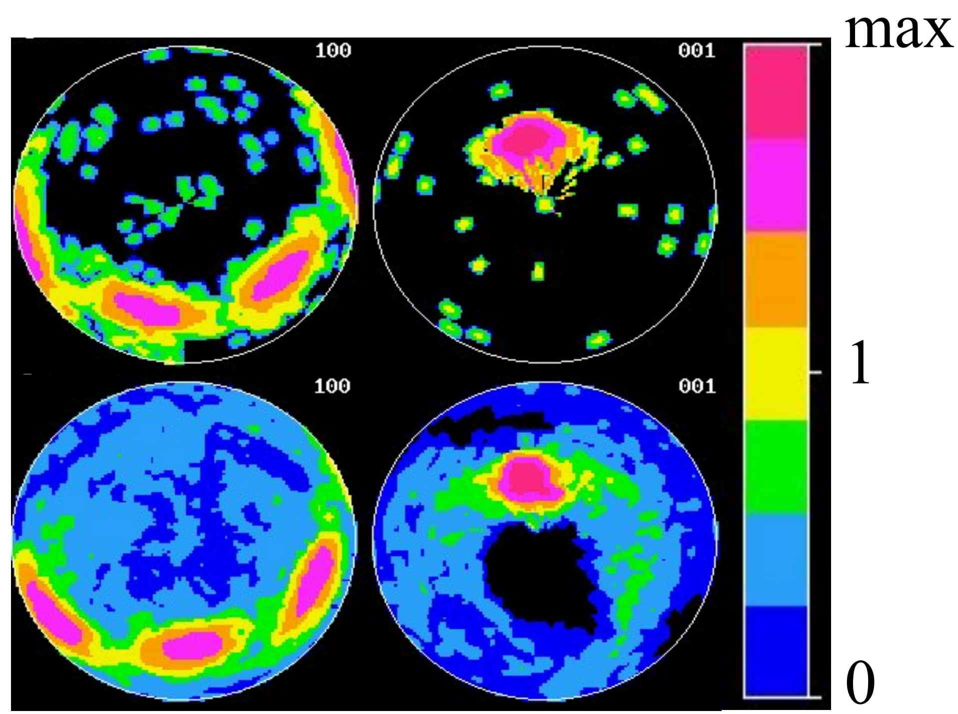
$OD_{max} = 347$ m.r.d.

EBSD versus X-rays: *Crassostrea gigas* (common oyster: Inner foliated calcite)



2604 measured
700 non-rejected

max = 84.7 m.r.d.

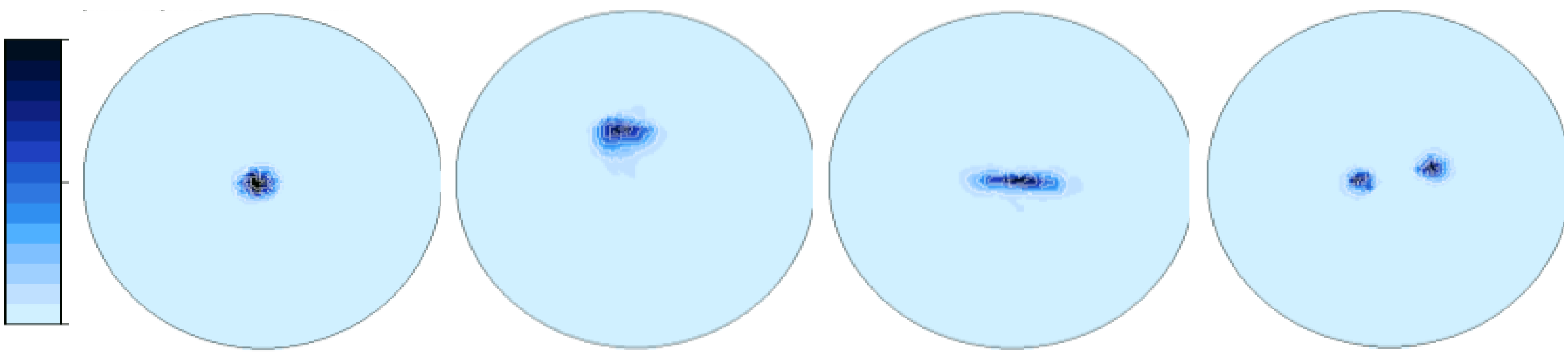


x-rays: $RP_{0.05} = 45\%$
$RP_1 = 31\%$

max = >100 m.r.d.

c-axes texture patterns

Pinctada maxima	*Nerita polita*	*Fragum fragum*	*Cypraea testudinaria*
ISN	ICCL	ICCL	ICCL
"gold pearl oyster"	"polished nerite"	"cockle"	"turtle cowry"



⊥	∠	∀	∨

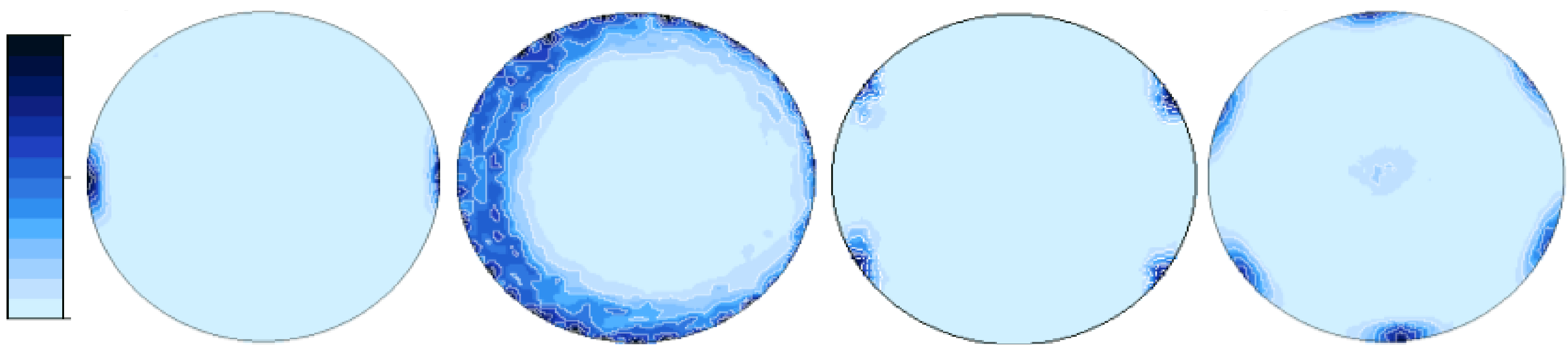
a-axes texture patterns

Helix pomatia
OCCL
"burgundy land snail"

Tectus niloticus
ICN
"commercial top shell"

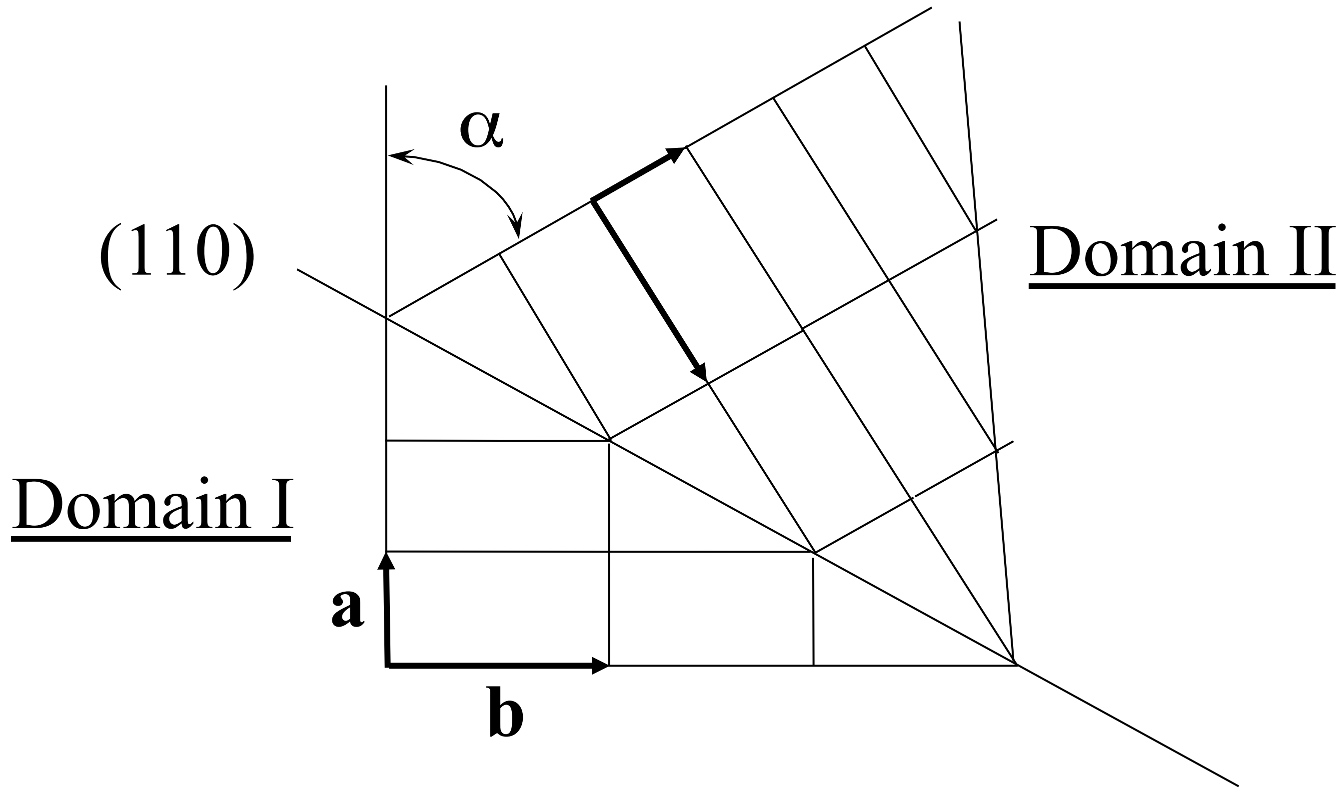
Conus leopardus
ICCL
"leopard cone"

Nautilus pompilius
ICN
"new caledonia nautilus"



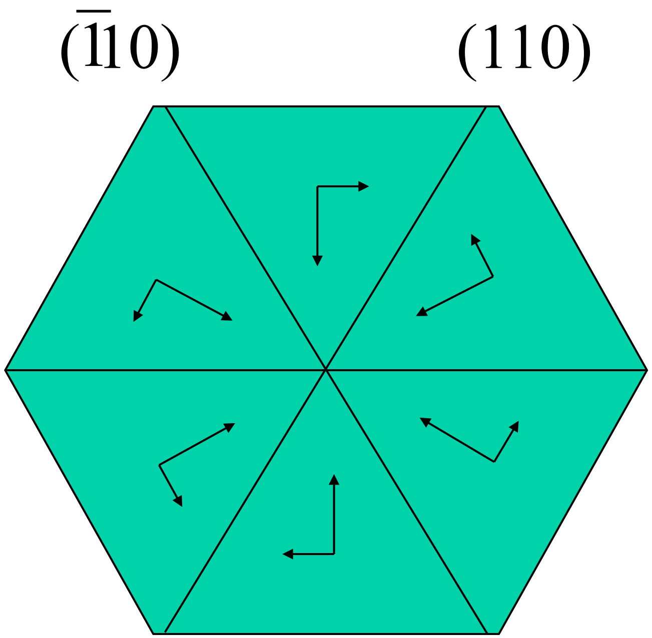
| ○ × *

Twinning in aragonite ...

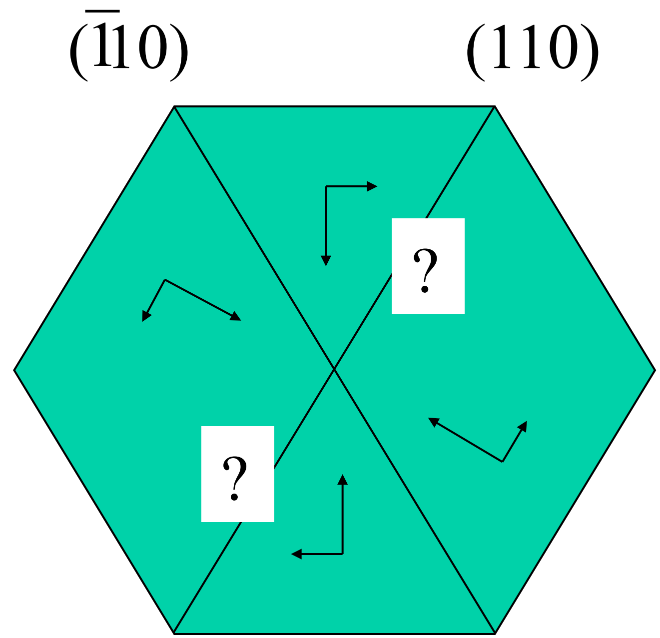


$\alpha = 2 \arctan(a/b) = 63.8°$

… forms nacre platelets ...

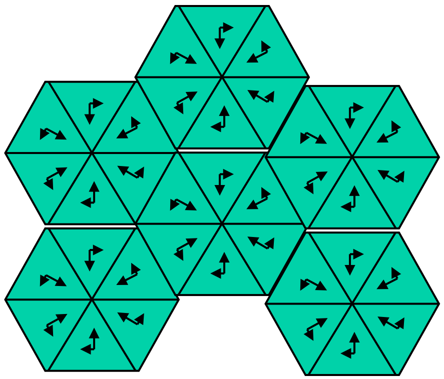


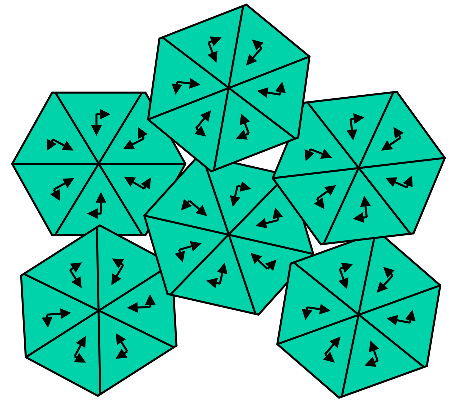
Bragg, 1937

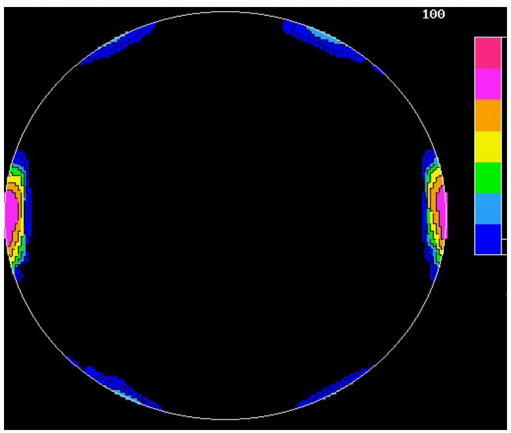


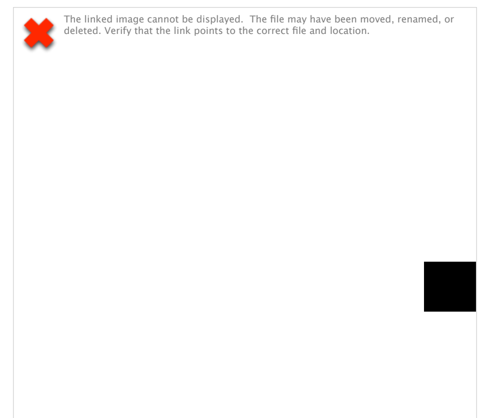
Mutvei, 1980

… that rearrange ...





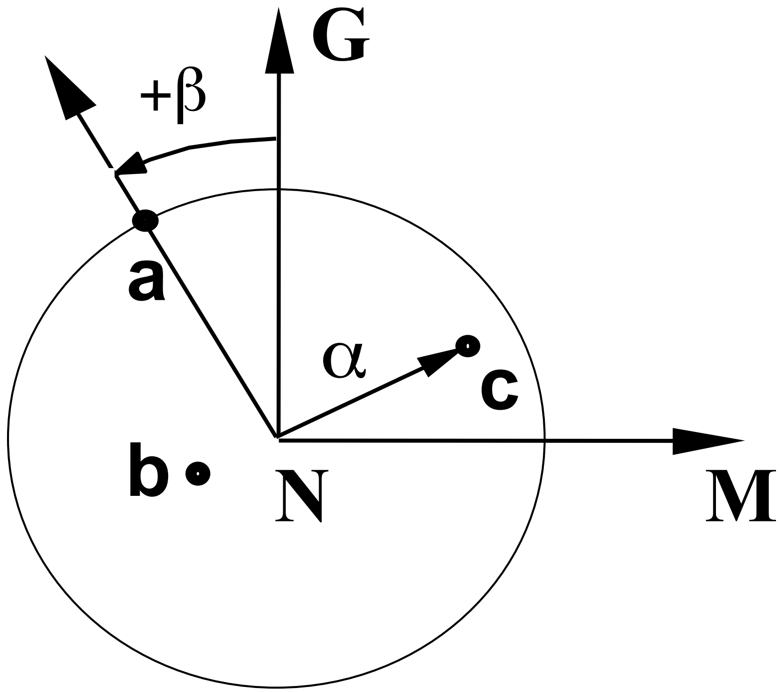




Pinctada margaritifera
(black pearl oyster)

Haliotis cracherodi
(black abalone)

Texture terms



$$\left\langle \mathbf{c}^{\alpha} \middle| \mathbf{L} \middle| \mathbf{a}_{\mathrm{T}}^{\langle hkl \rangle,\beta} \right\rangle$$

c: ● , ∀, ∨, ∠, ⊥

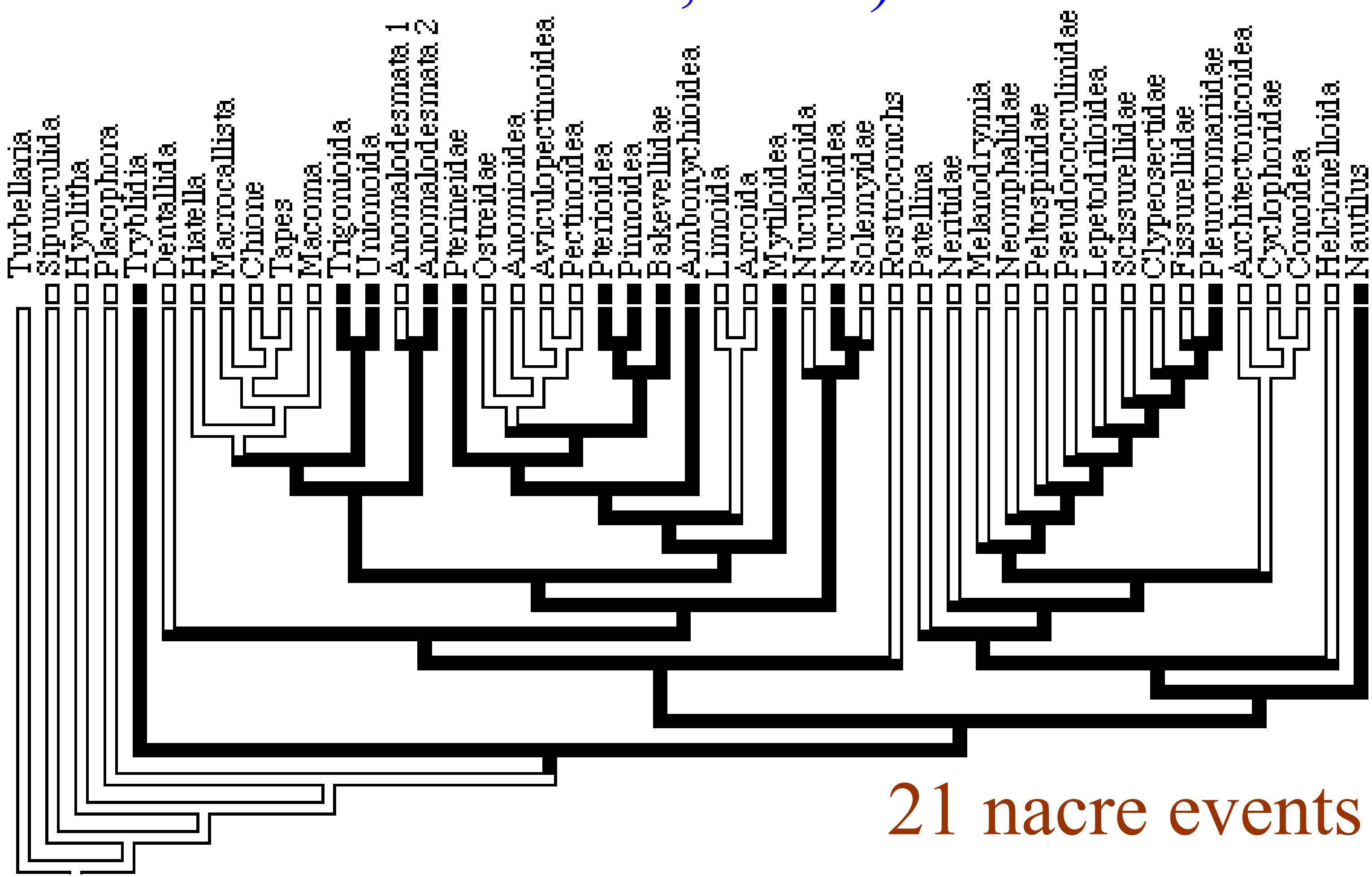
a: ● , **o**, *, ×, |

L: ISN, ICN, ICCL

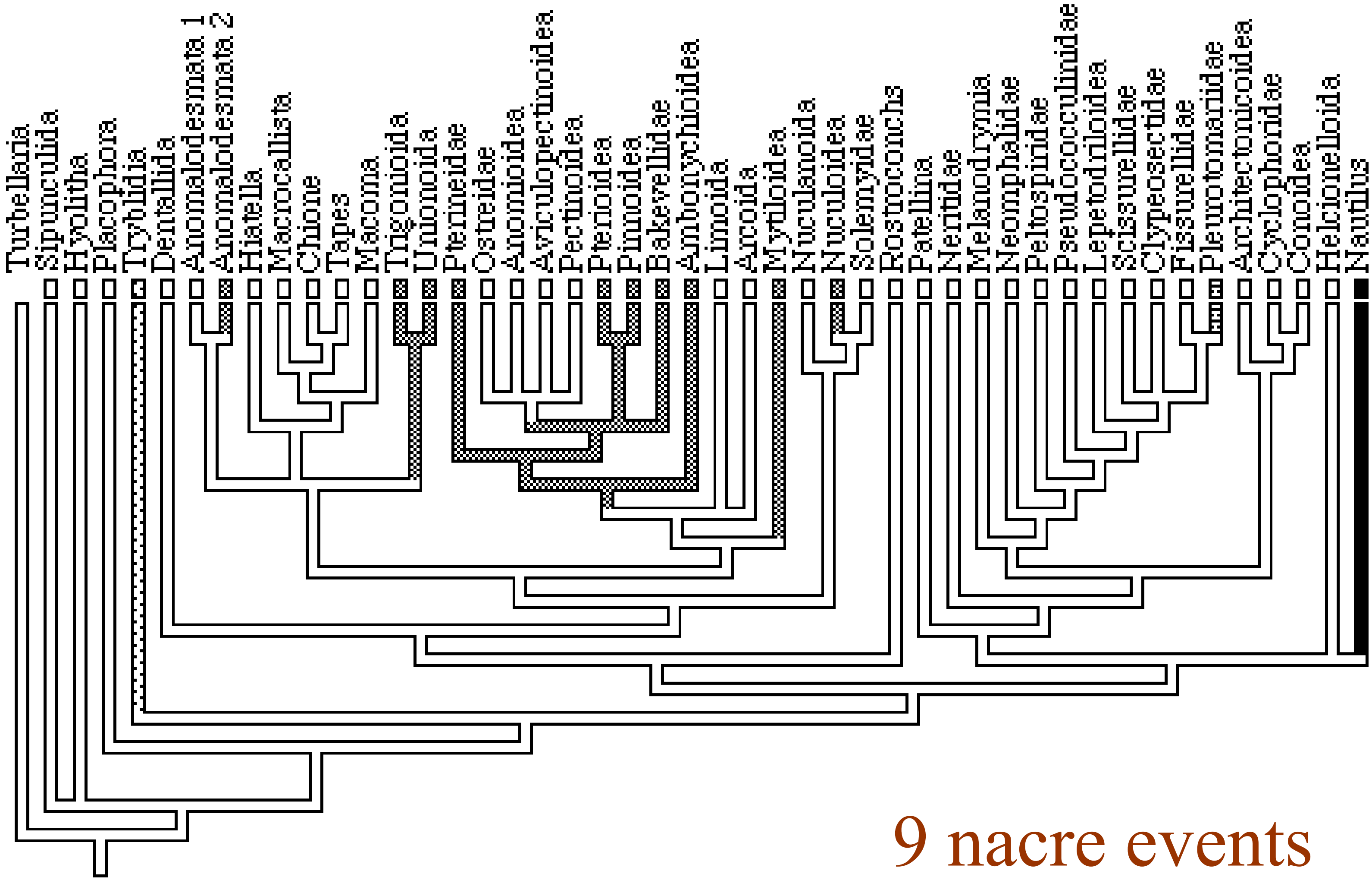
T: % twinned volume

<hkl>: direction in (**G**,**M**)

Phylogenic interest: nacre = ancestral (Carter & Clarck, 1985)



nacre not ancestral



9 nacre events

Conclusions

- Texture analysis of shells may be quantitatively operated, with x-rays and electrons
- Shells exhibit a large variety of texture patterns, from random to single crystal-like
- Textural parameters are similar for close species, different for distant species
- These parameters can be summarised by a “texture term” useful for species comparison
- “Texture” characters can be relevant for classification and phylogenetic interpretation through cladistic analysis

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Station Biologique Roscoff

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