Microstructures, textures and material properties of marble rocks

Paolo Conti

conti@unisi.it

UNIVERSITÀ DI SIENA 1240 | Centro di GeoTecnologie, Italy

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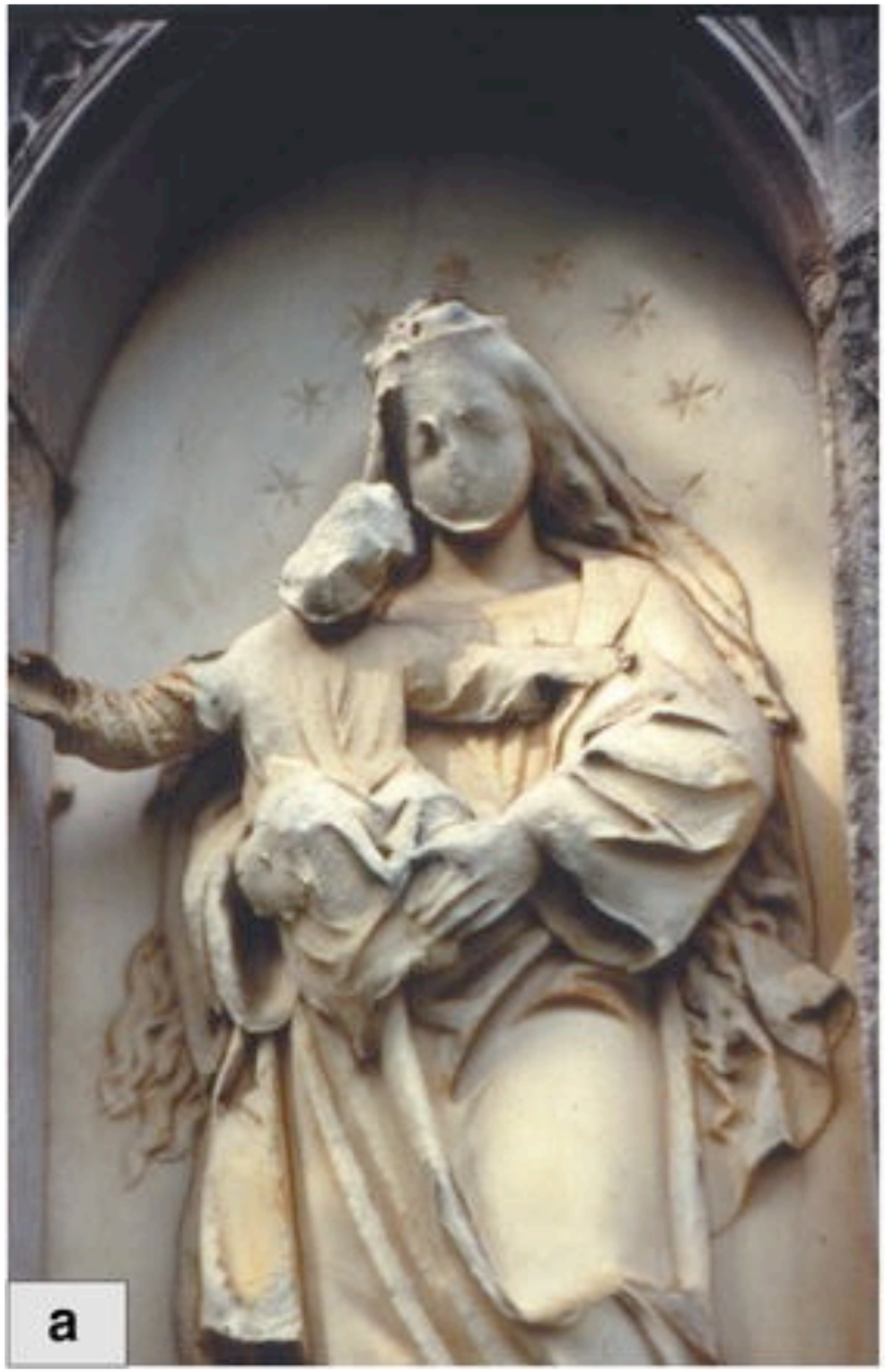
- Marble behaviour
- Crystal structure of minerals and rocks
- Rock fabrics
- Marble deterioration
- Mechanical properties
- Natural examples

Marbles: different behaviour

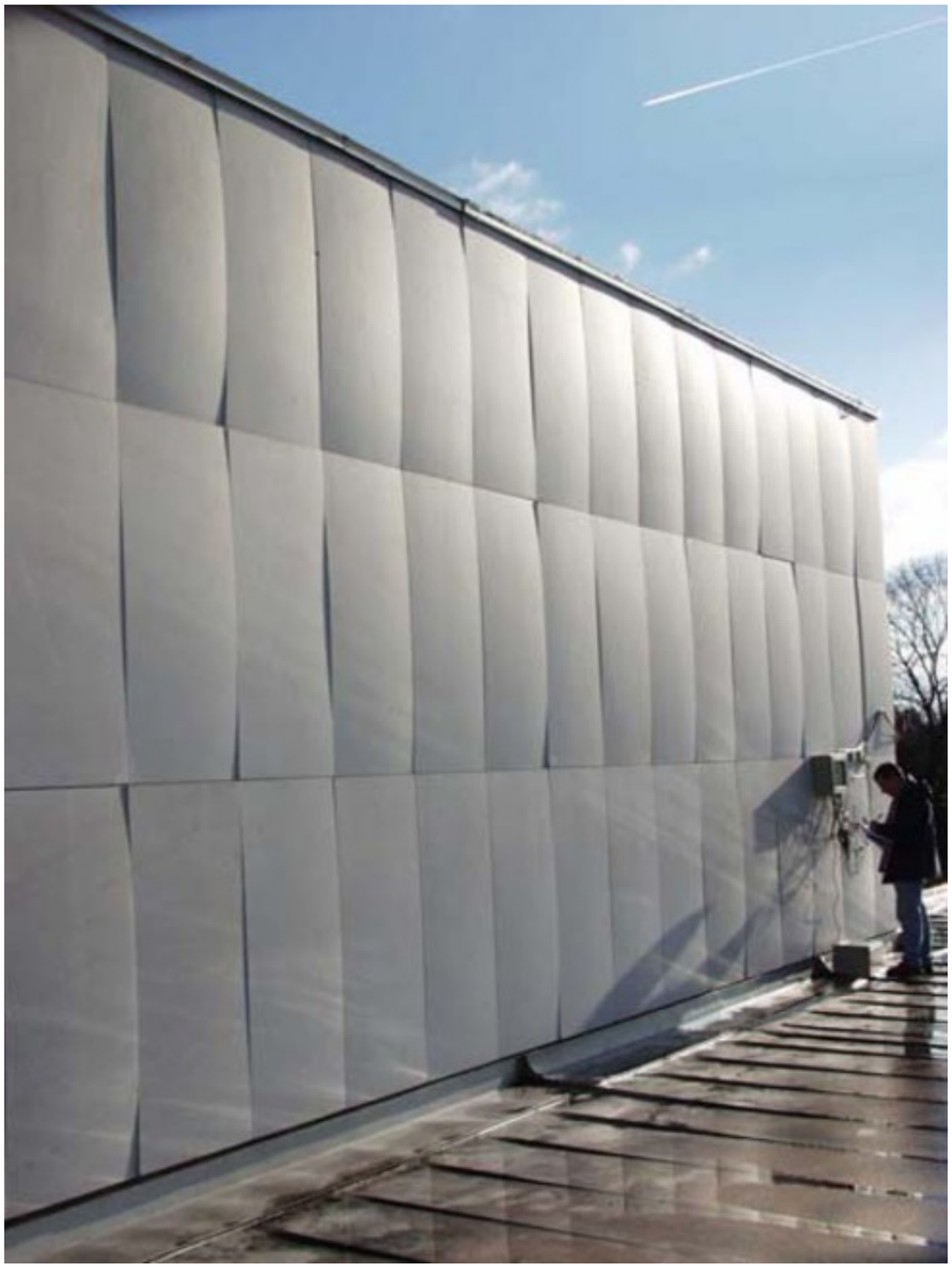
(Ephesus, Turkey)



(from Shushakova et al., 2010)

Marbles: different behaviour

panels



Marbles: different behaviour

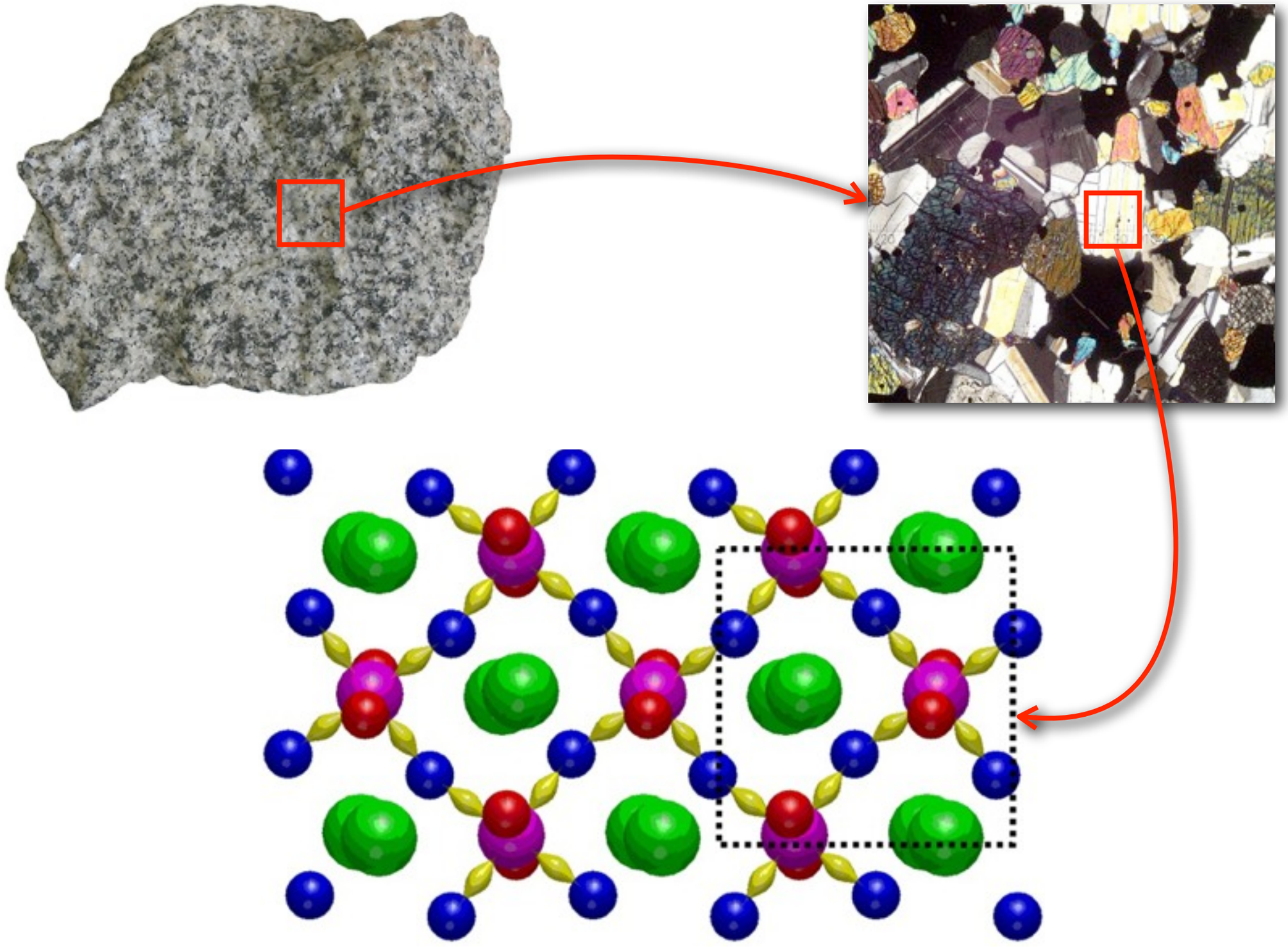
Marbles

Same composition (≃100 % $CaCO_3$)

Different behaviour due to:

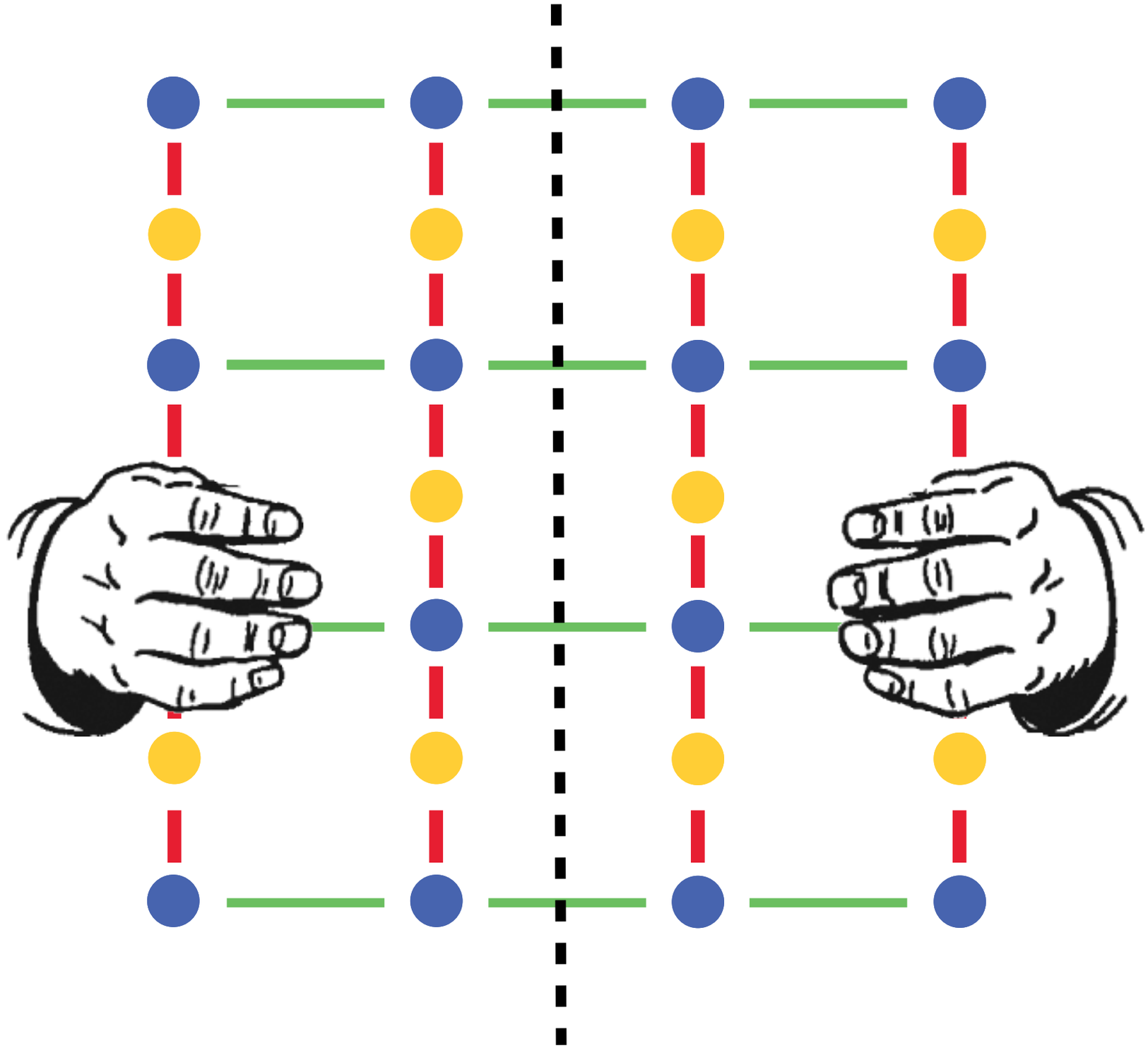
- anisotropic physical properties of calcite crystals
- texture of rocks
- microstructure of rocks

Anisotropic physical properties:
Crystal structure of rocks



Anisotropic physical properties: strength

crystal

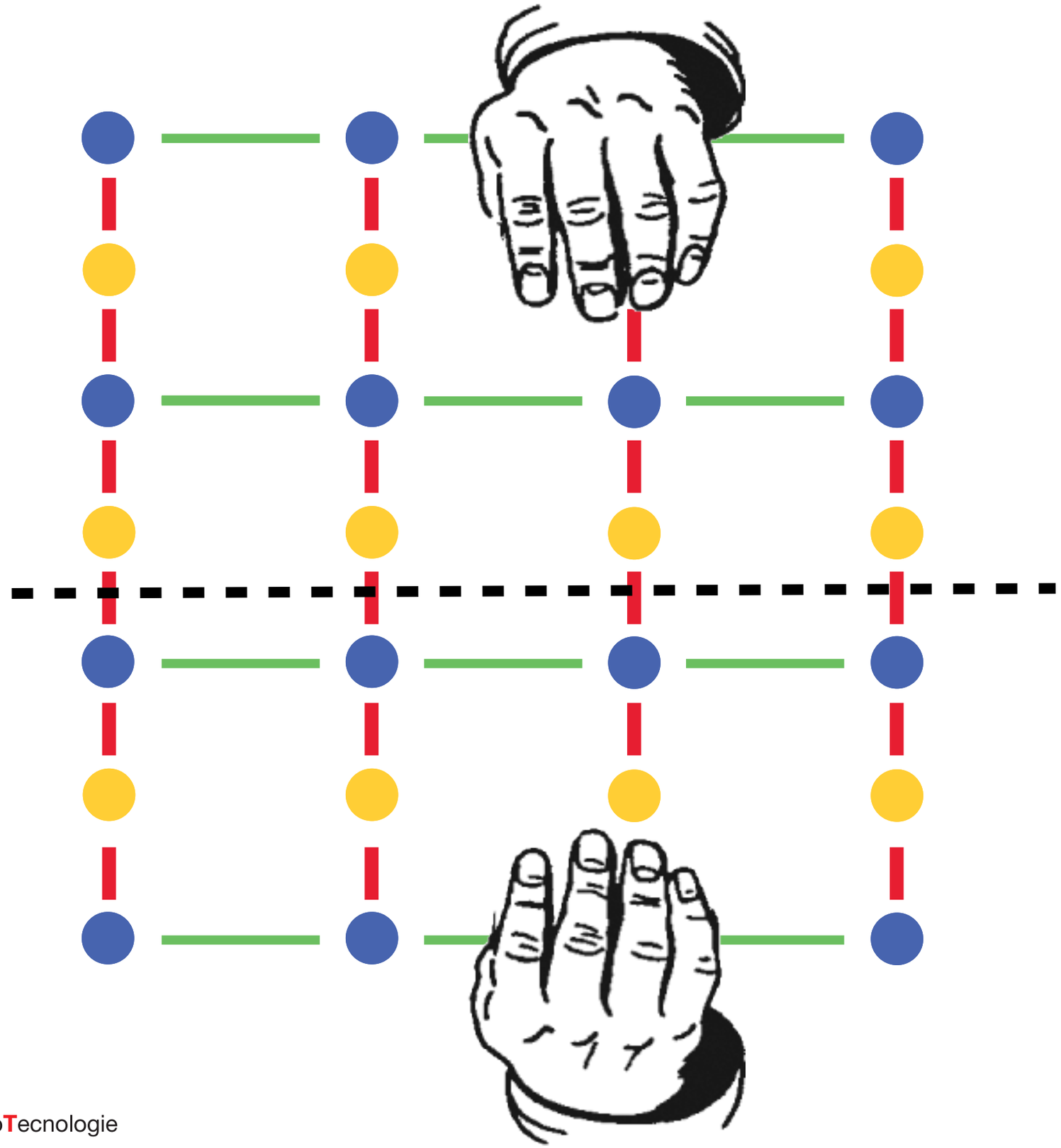


"weak" bond

"strong" bond

Anisotropic physical properties: strength

crystal

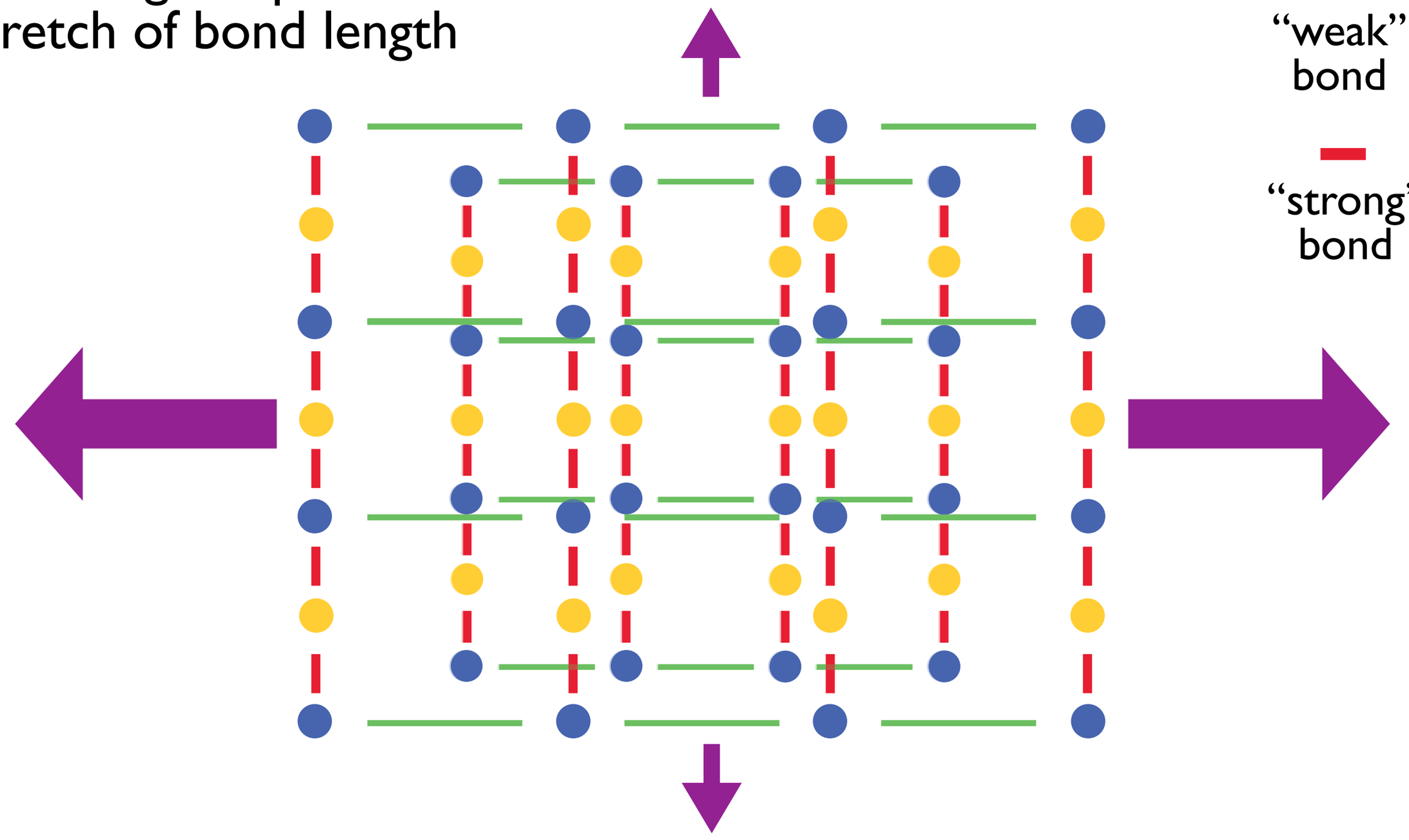


"weak" bond

"strong" bond

Anisotropic physical properties: thermal expansion

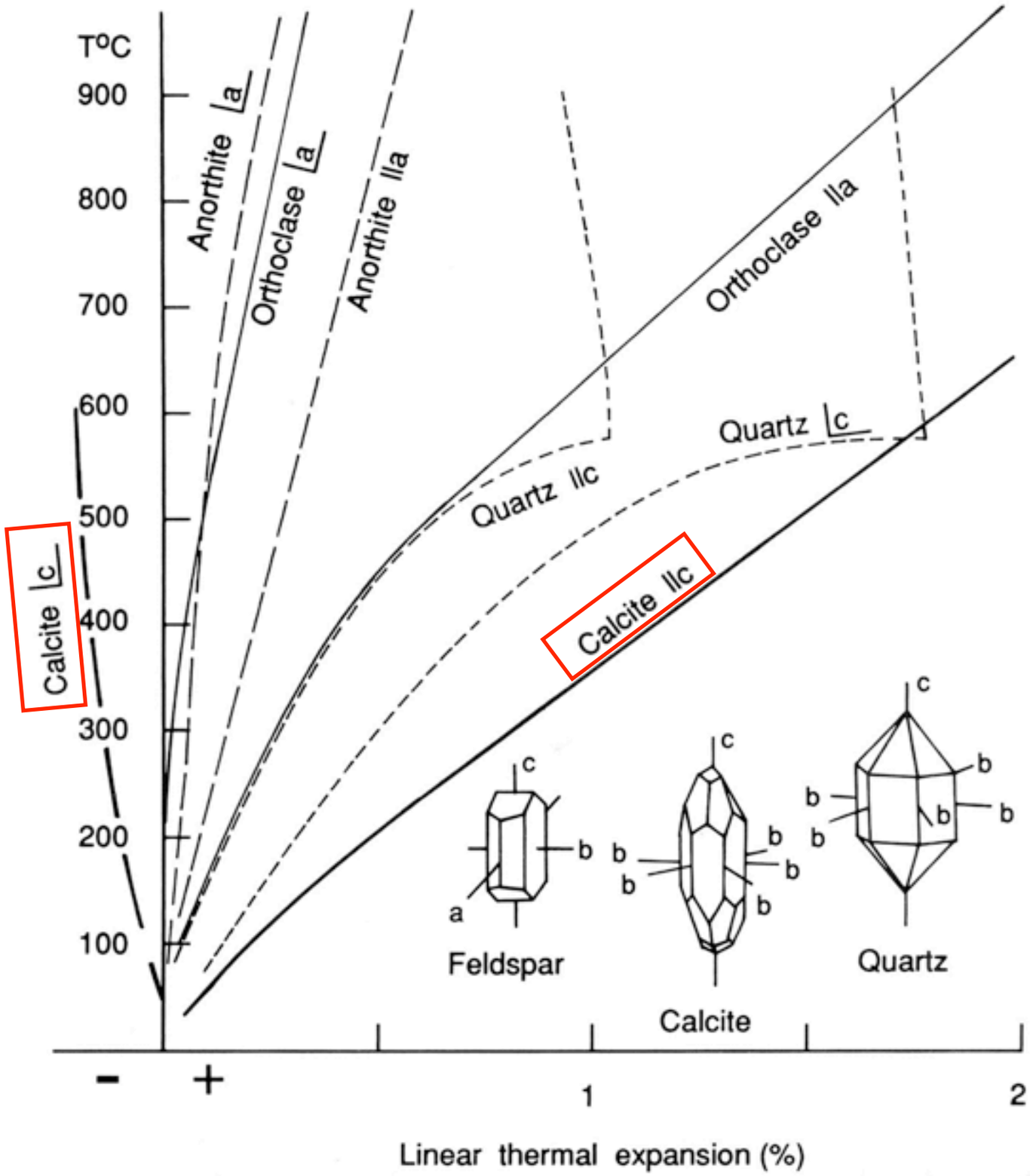
Increasing temperature:
stretch of bond length



"weak" bond

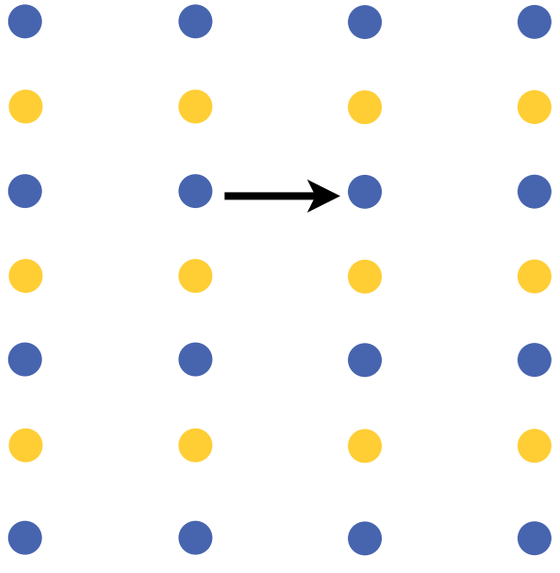
"strong" bond

Anisotropic physical properties:
thermal expansion



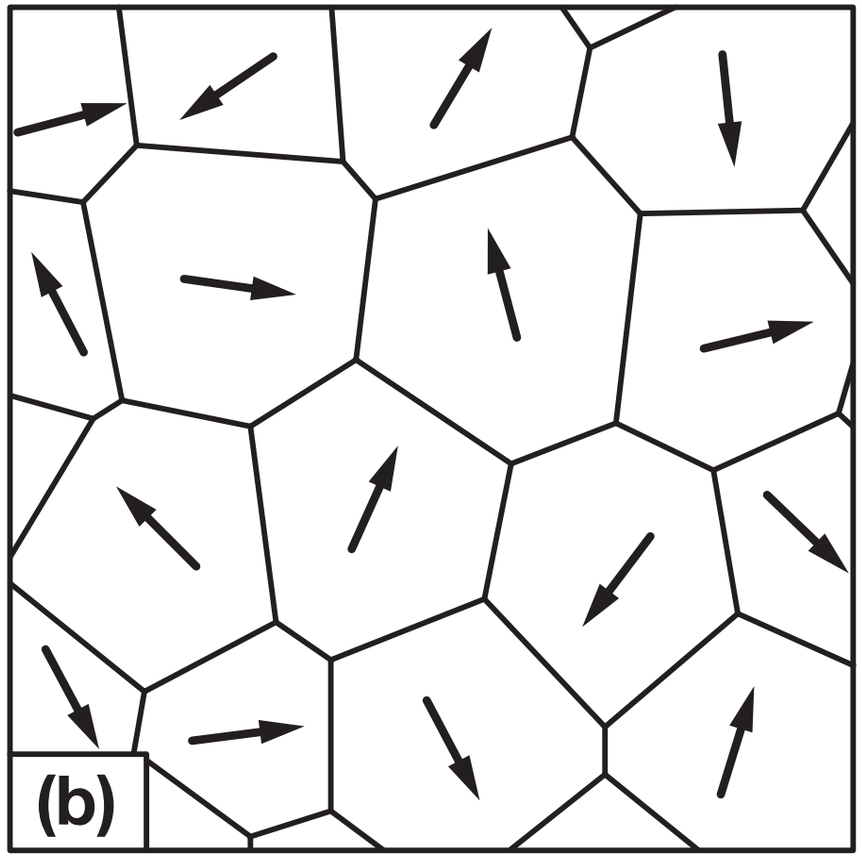
(Winkler, 1994)

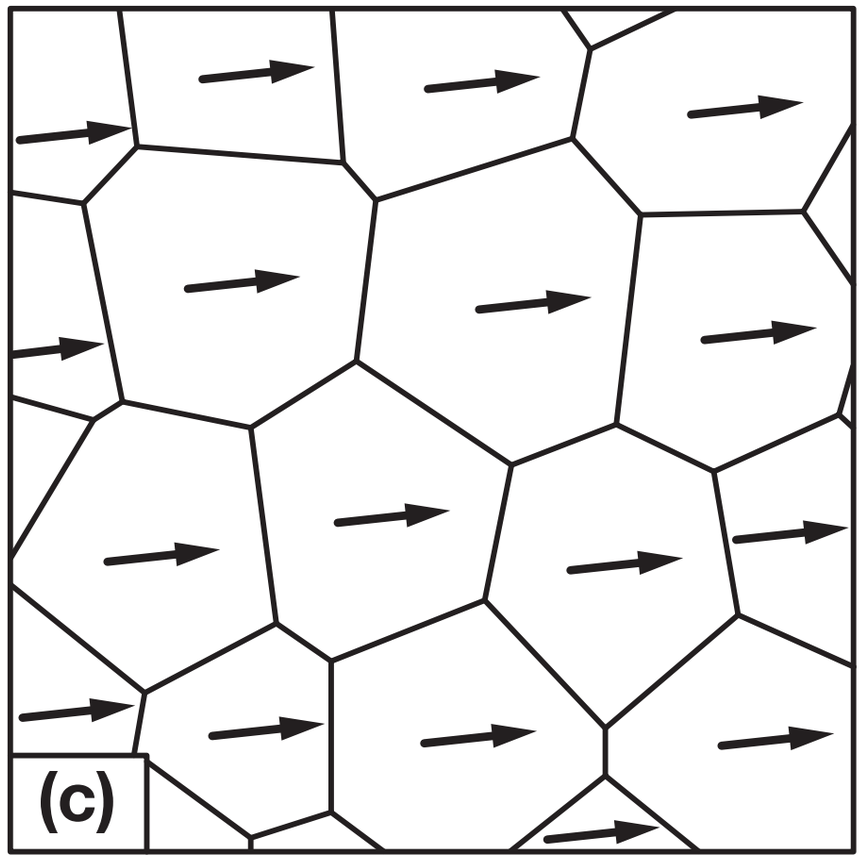
Anisotropic physical properties:
natural texture



crystallographic direction

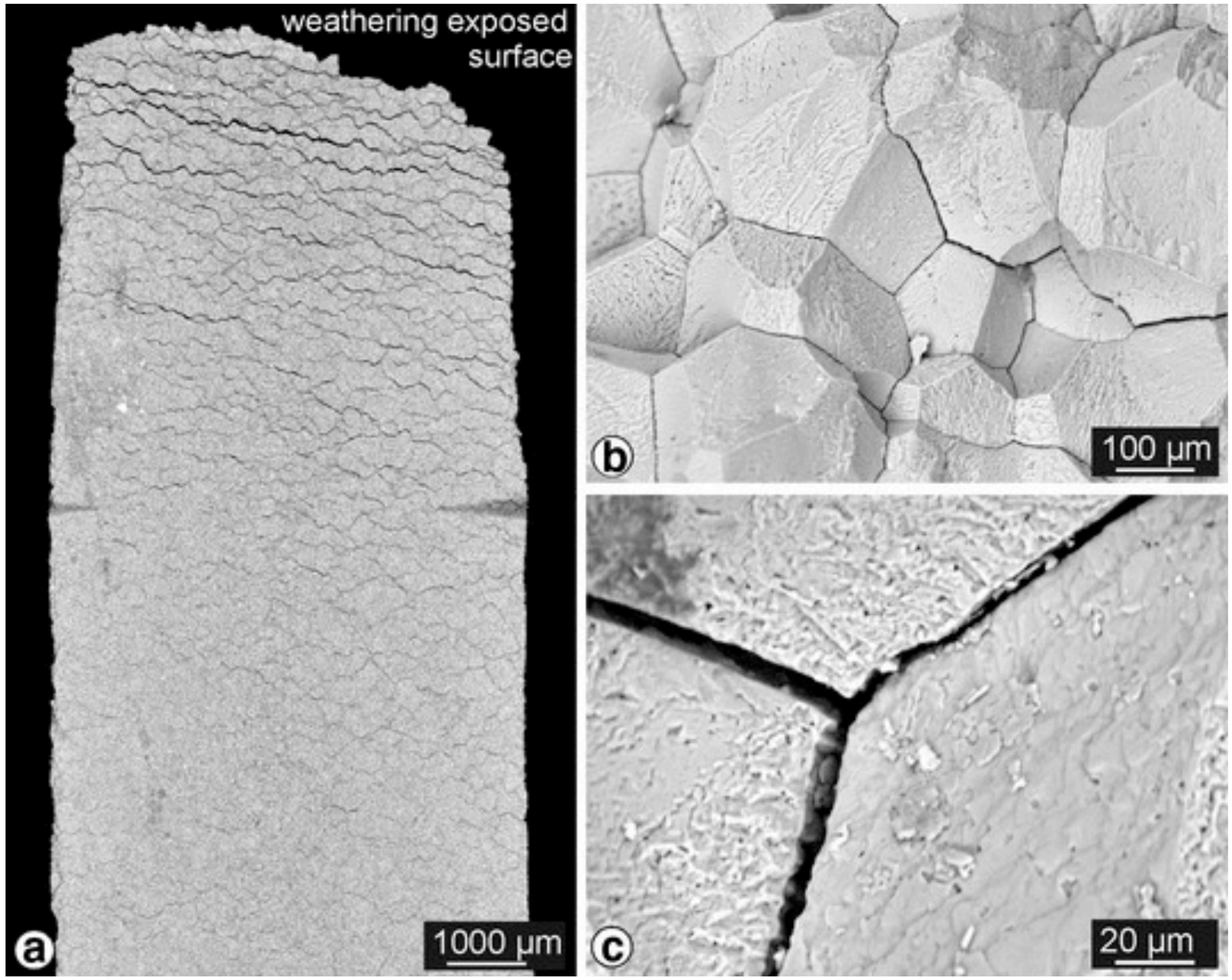
weak crystallographic preferred orientation





strong crystallographic preferred orientation

Anisotropic physical properties: shapes

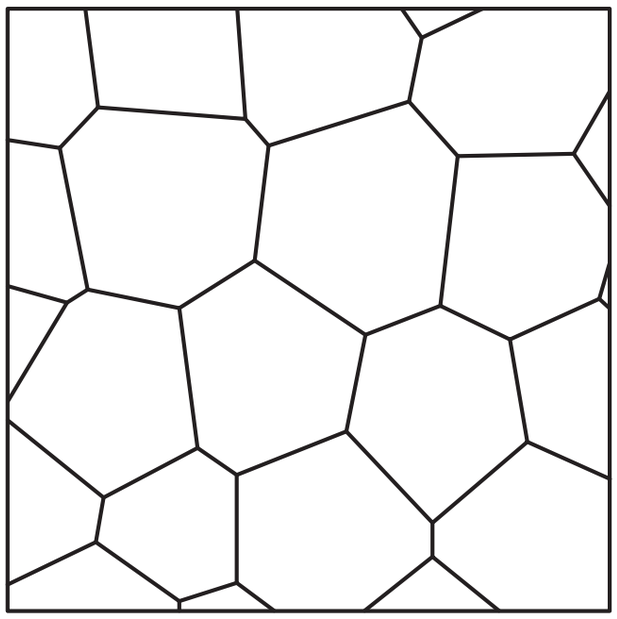


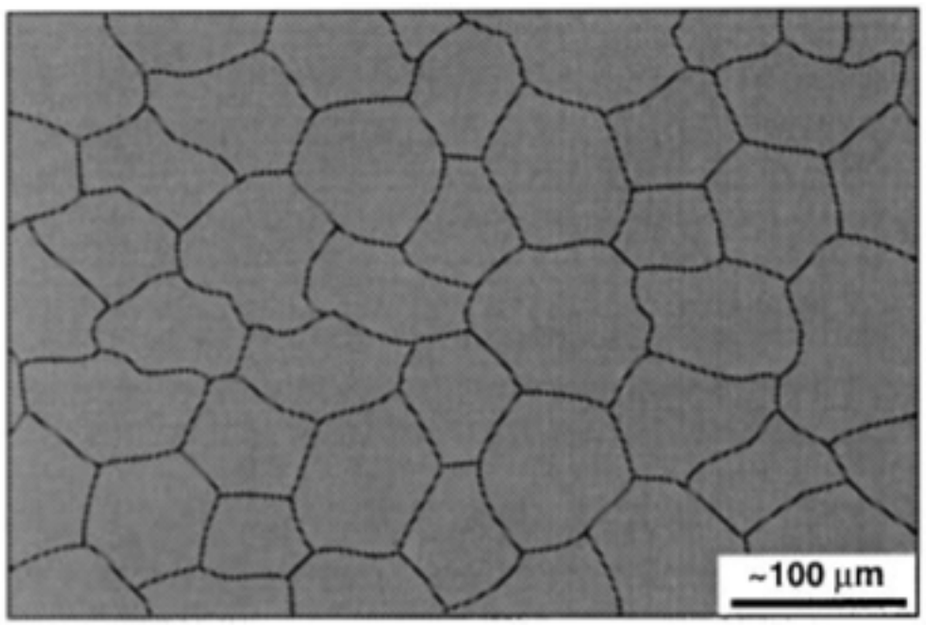
(Ruedrich et al., 2011)

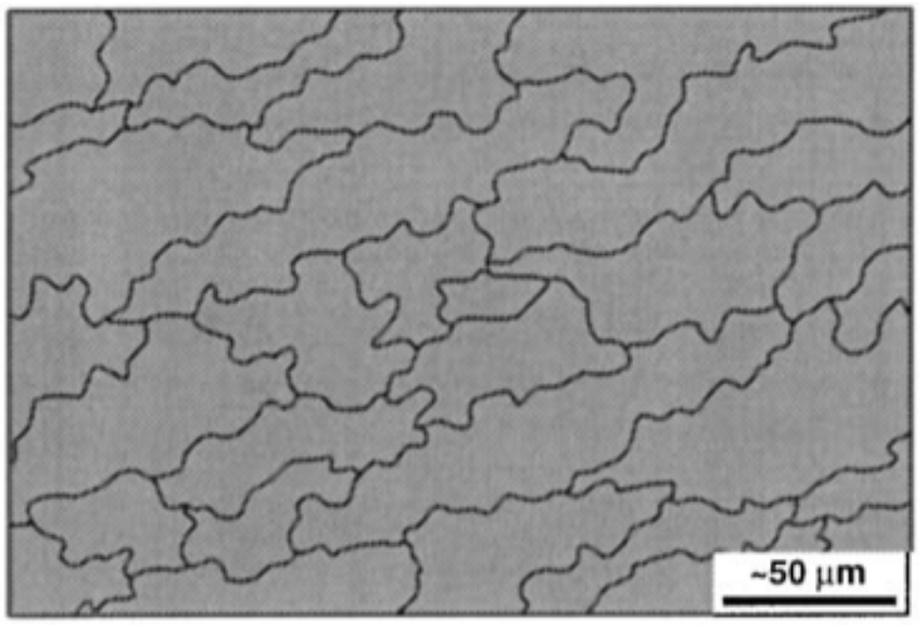
Along grain buondaries, weatering: micro-karst, breakouts, coloration, formation of crusts, biological colonization, granular desintegration, peeling, moisture expansion, etc.

Superficial disintregration - loss of cohesion (dilatancy) - total decay of the material

Anisotropic physical properties: shapes







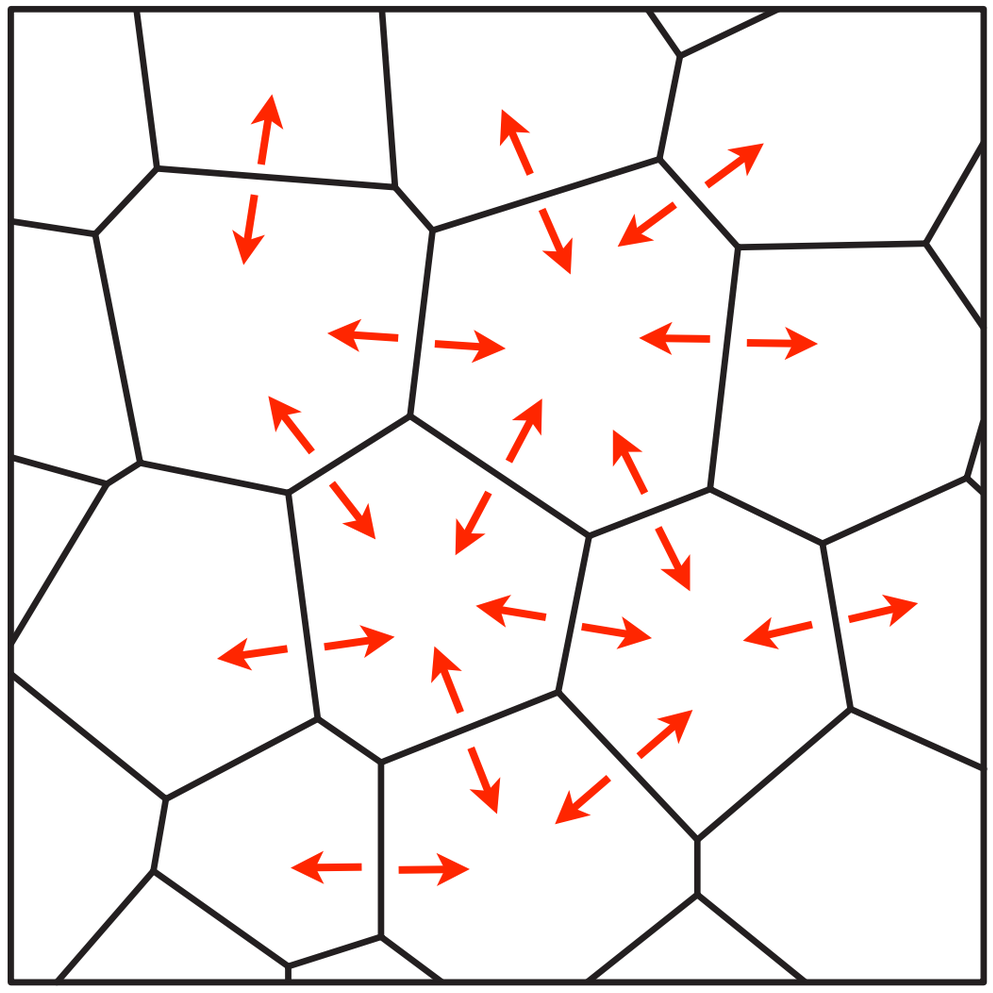
straight grain boundaries

"slide"

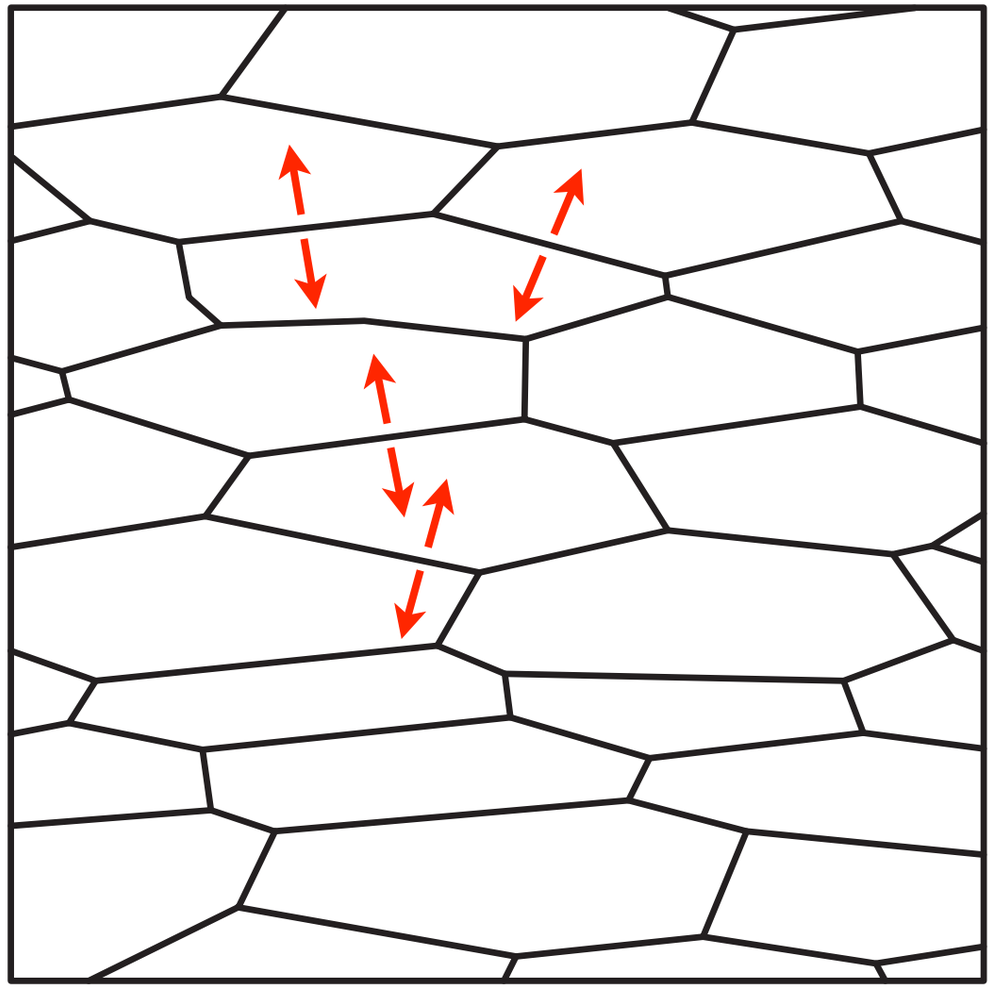
lobate grain boundaries

"locked"

Anisotropic physical properties: shapes



no shape preferred orientation of crystals

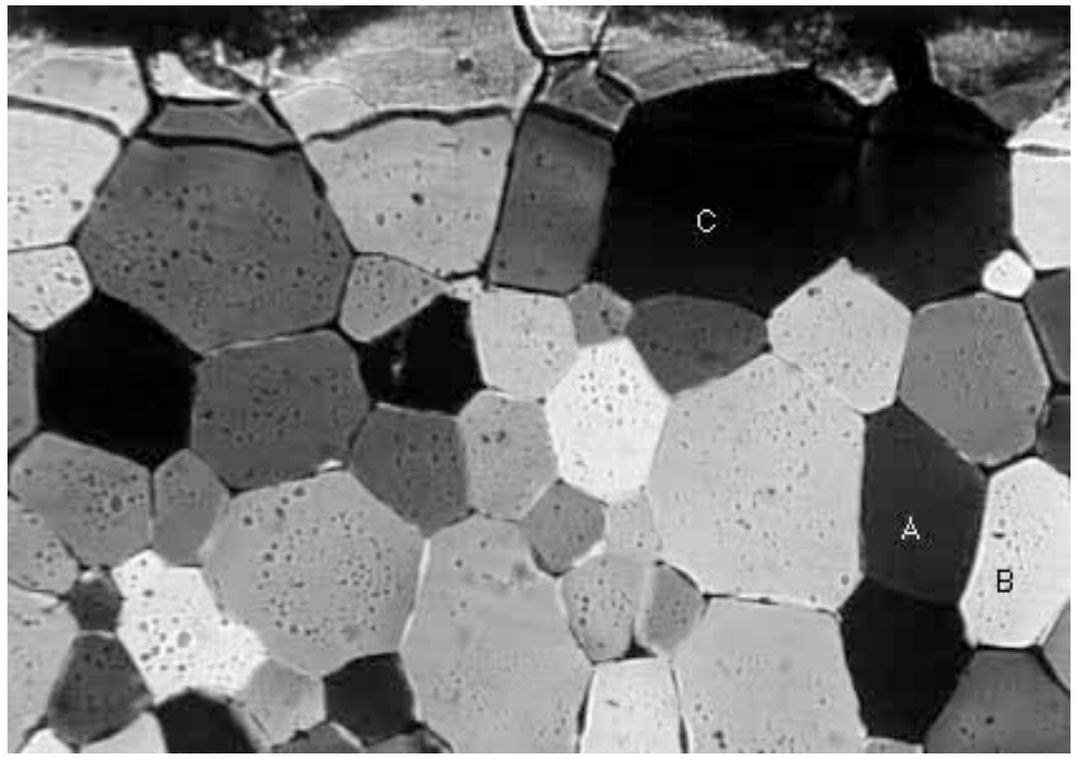


shape preferred orientation of crystals

(anisotropic volume increase)

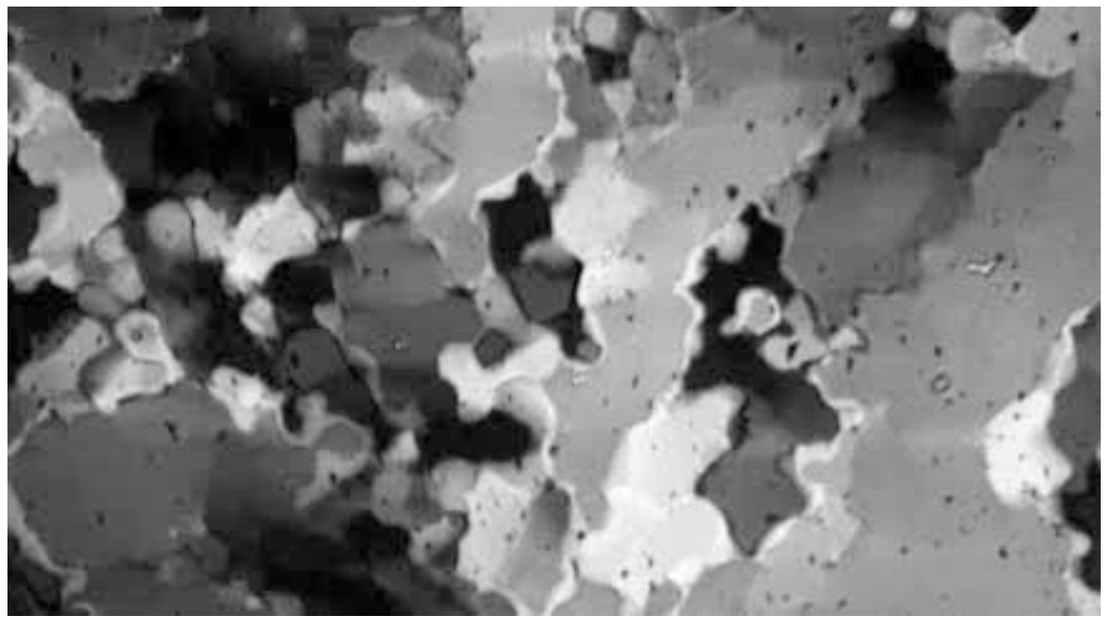
Developement of microstructures (movies)

dynamic
(syn-tectonic)
recrystallization



before:
no shape preferred orientation, straight grain boundaries

static
recrystallization
(annealing)

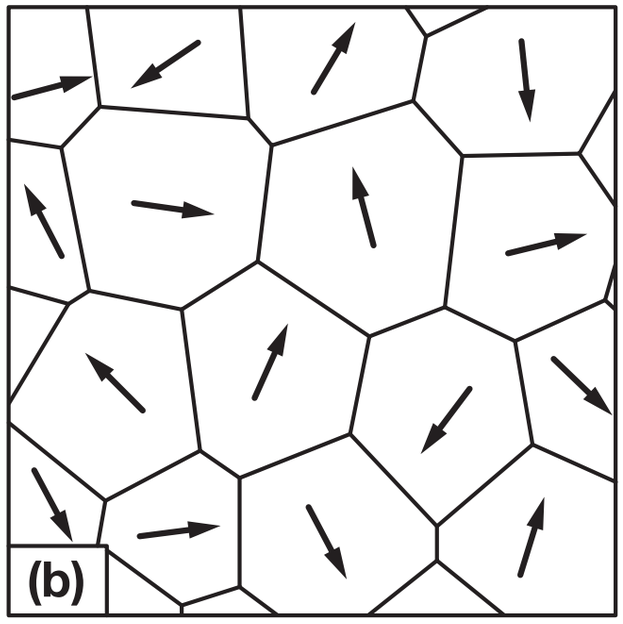


before:
shape preferred orientation, lobate grain boundaries

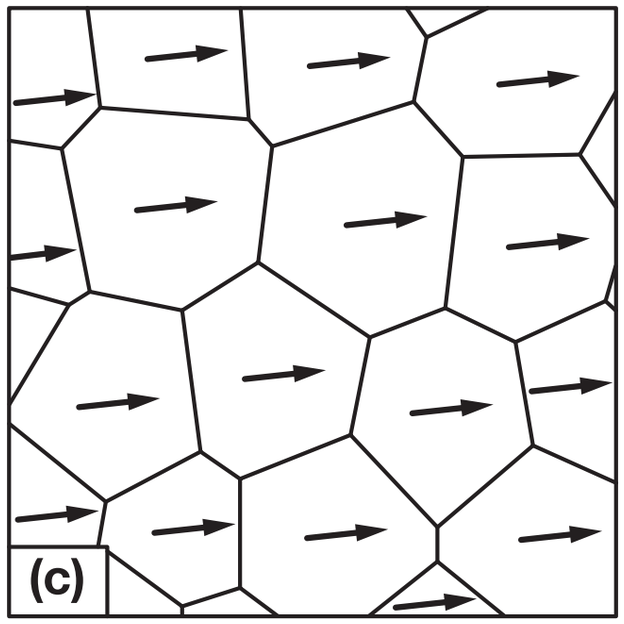
Octachloropropane (organic material)
Means et al. (1994) J. Struct. Geol.,16, 403-418

http://www.atmos.albany.edu/geology/webpages/wdmovies/wdmoviep.html

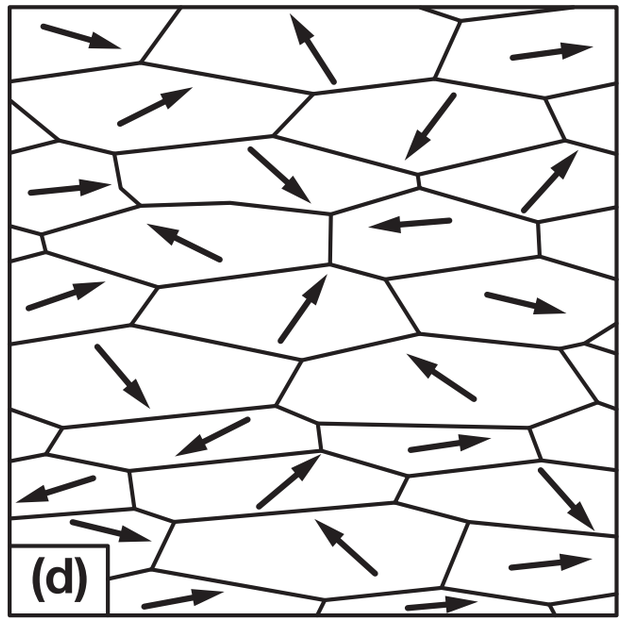
Anisotropic physical properties



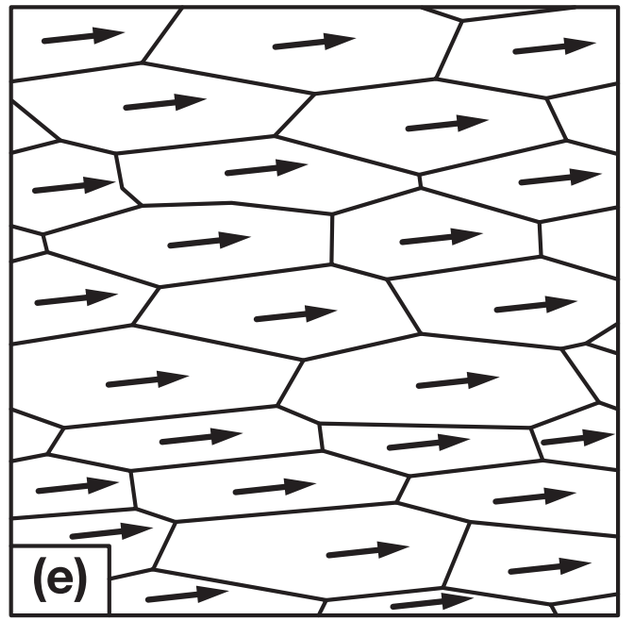
- no shape preferred orientation of grains
- no crystallographic preferred orientation



- no shape preferred orientation of grains
- crystallographic preferred orientation



- shape preferred orientation of grains
- no crystallographic preferred orientation



- shape preferred orientation of grains
- crystallographic preferred orientation

crystallographic preferred orientation of crystals = <u>texture</u> of rock

shape preferred orientation of crystals = <u>microstructure</u> of rock

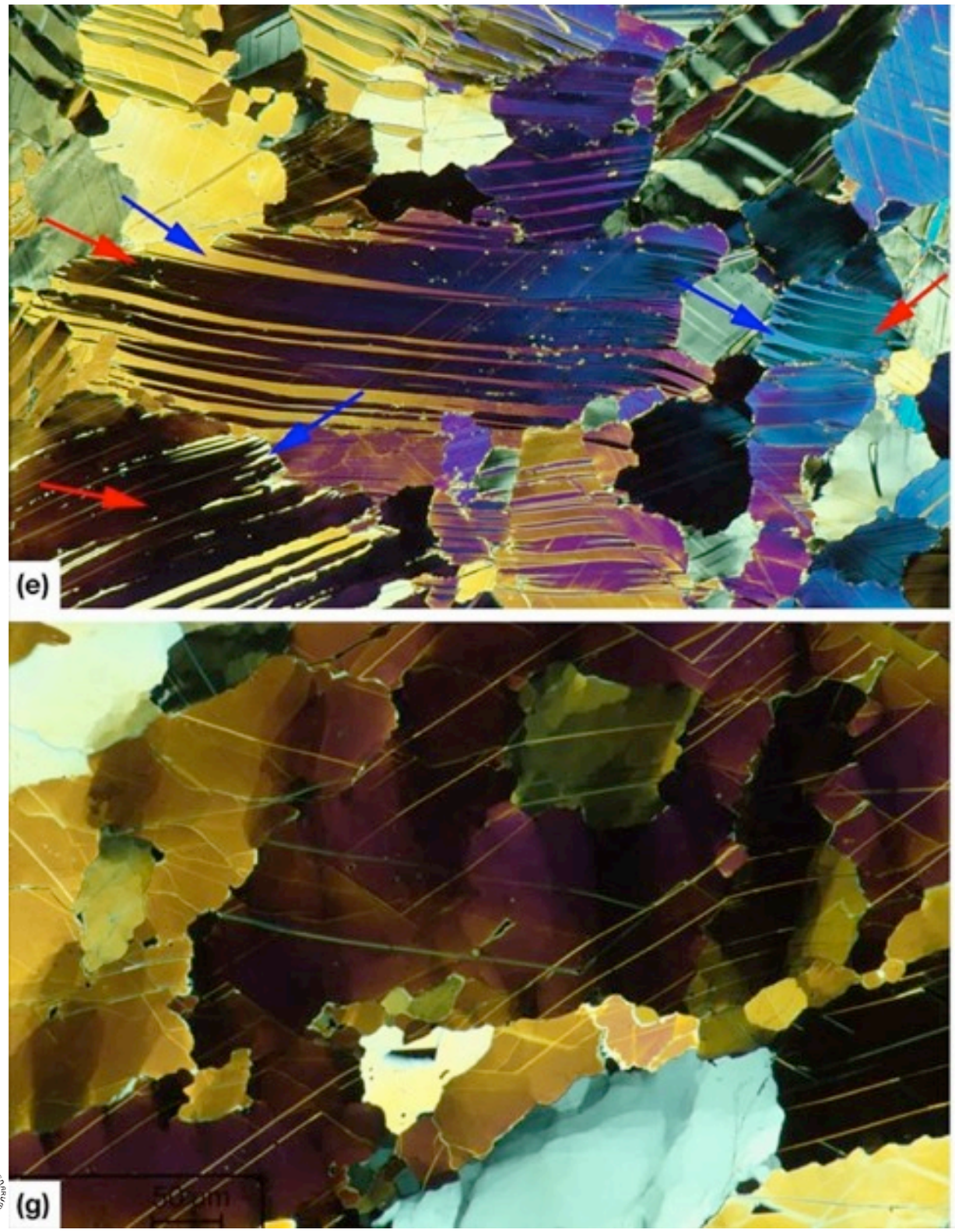
(texture + microstructure = <u>fabric</u>)

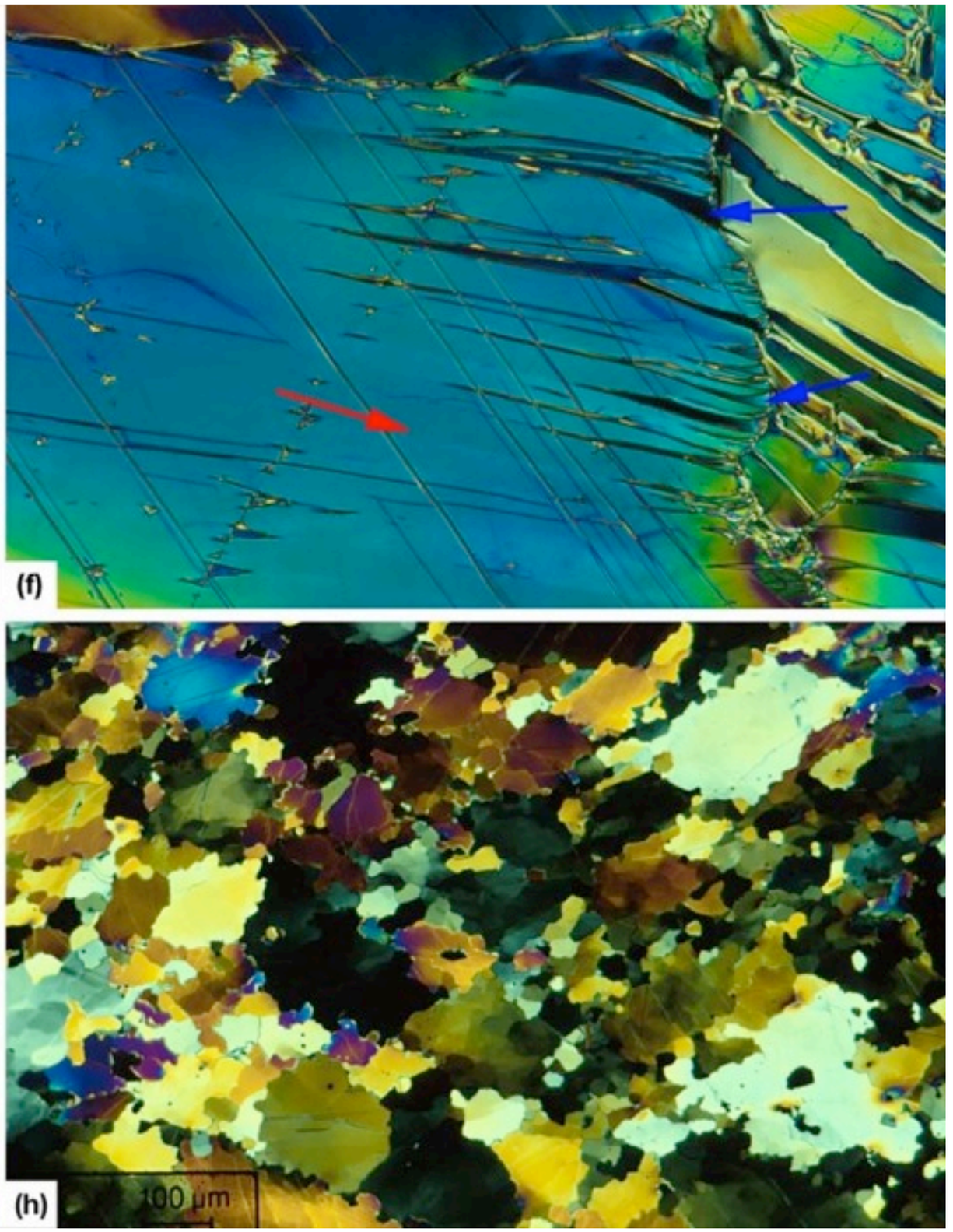
In marbles...

limited informations from outcrop studies only

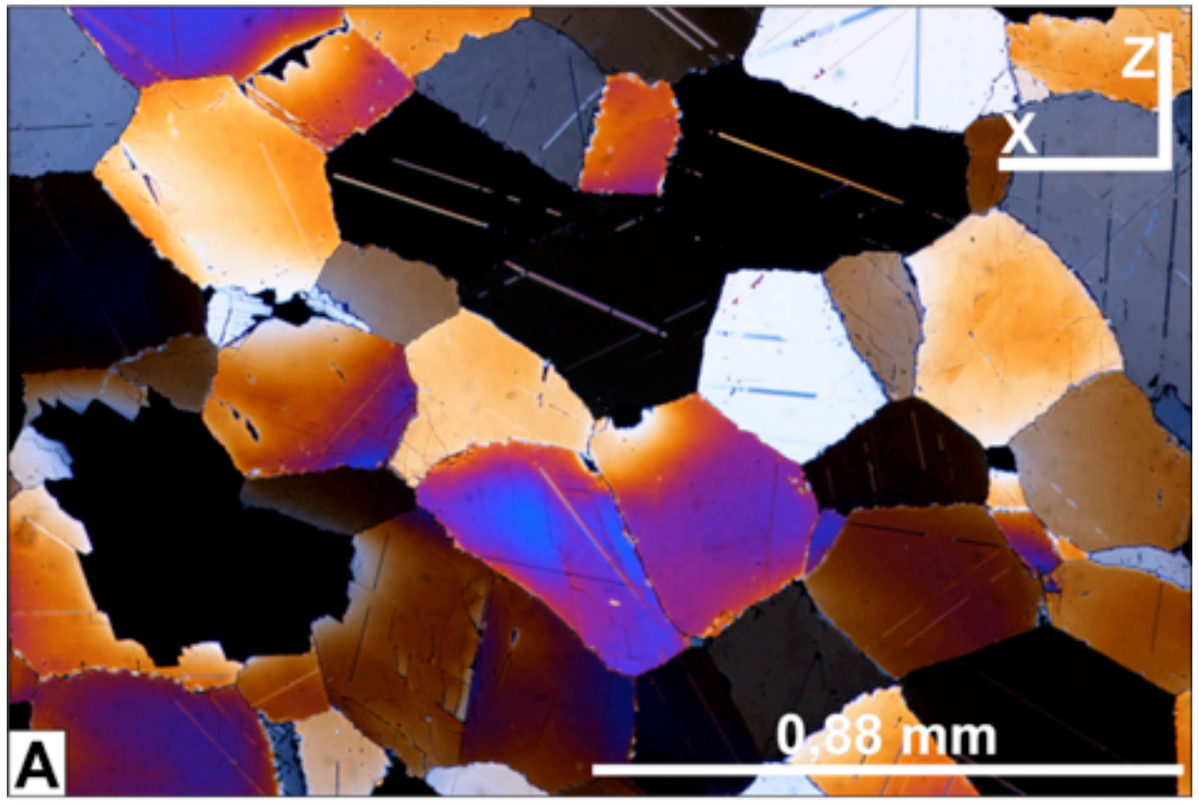
Microstructures in marbles

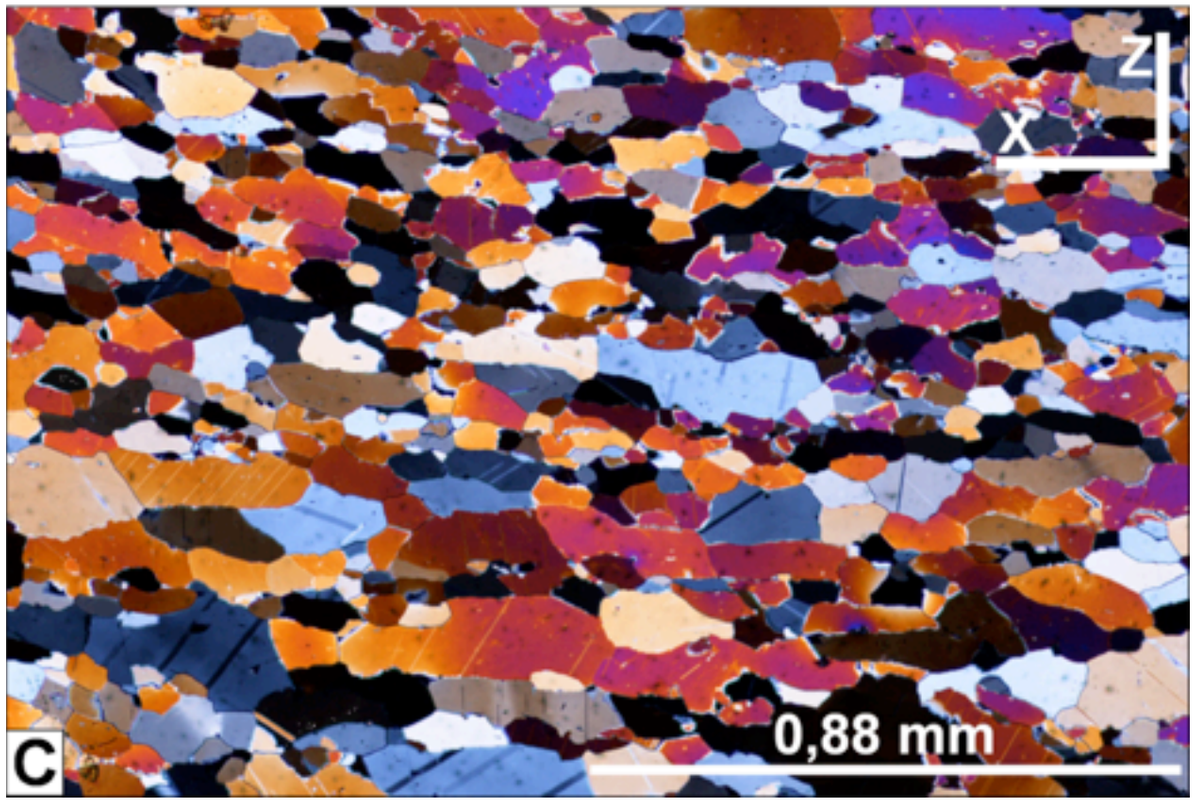
“ultra” thin section (<8 μm)



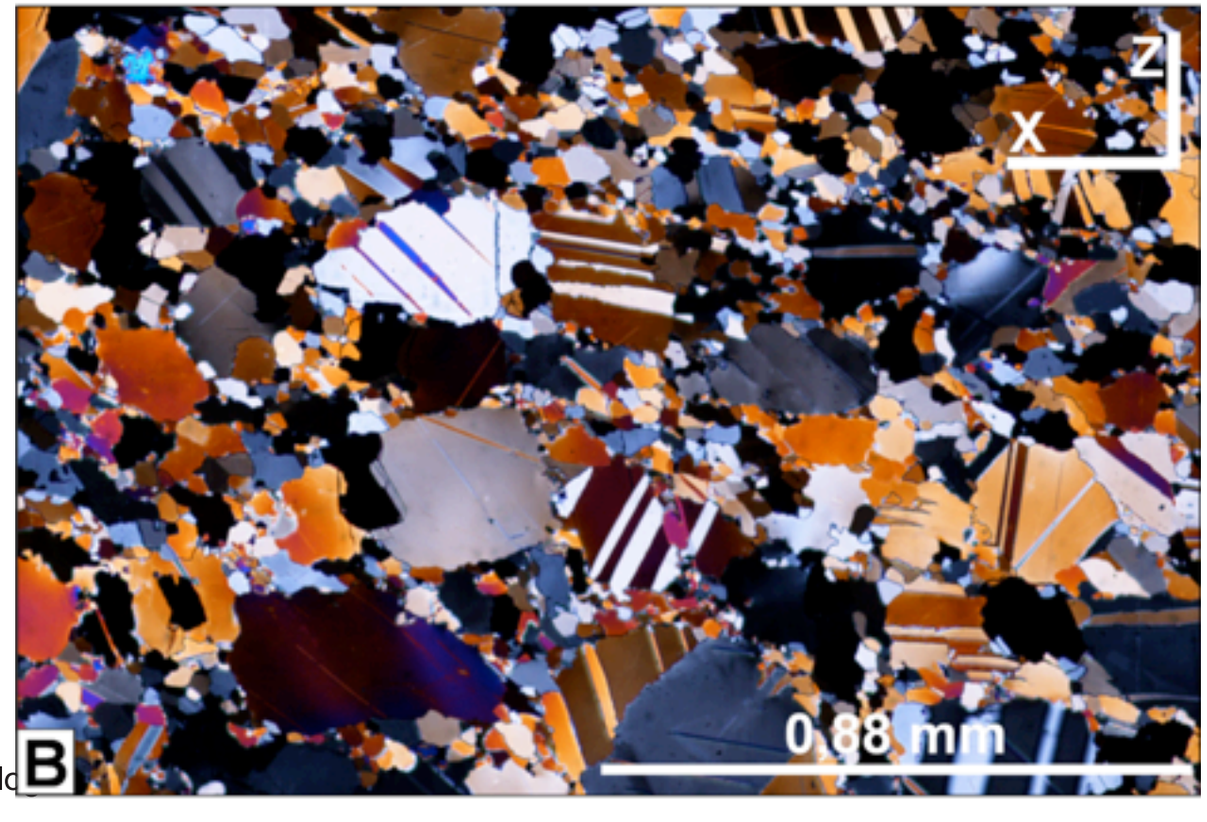


Microstructures in marbles



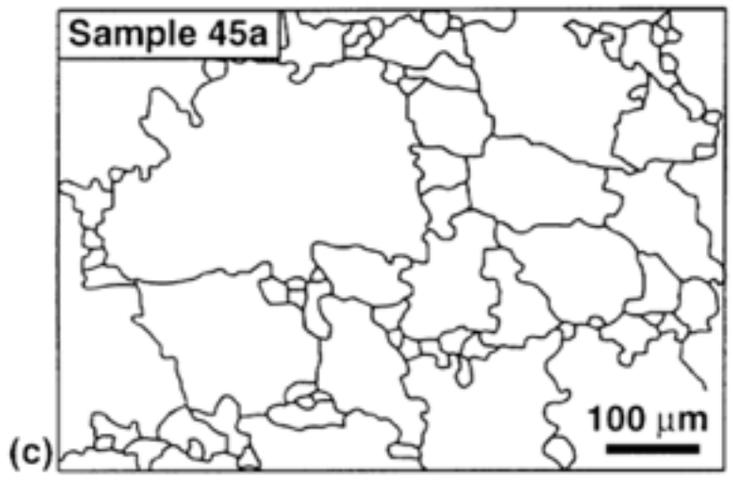


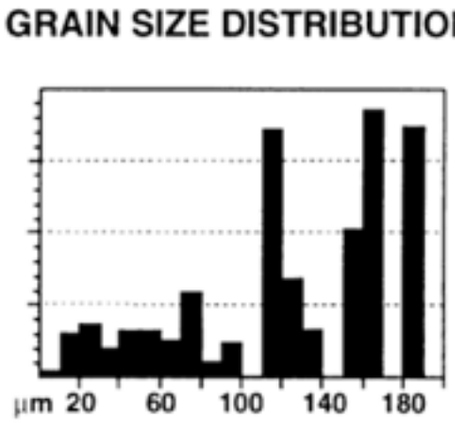
Carrara marble (Italy)

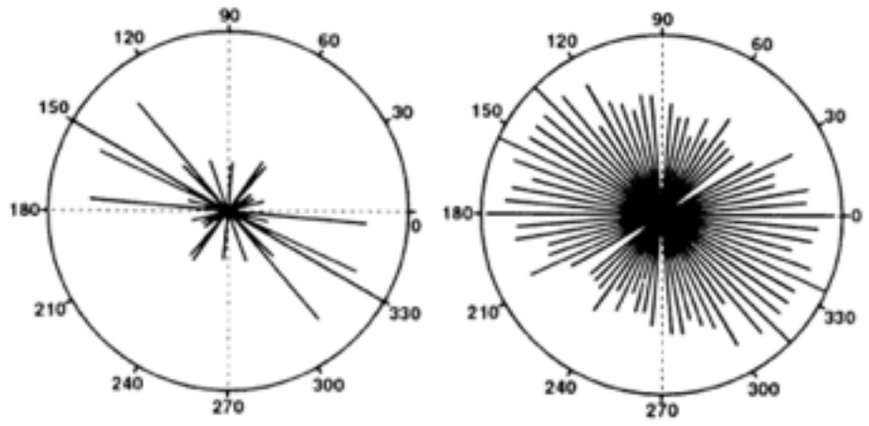


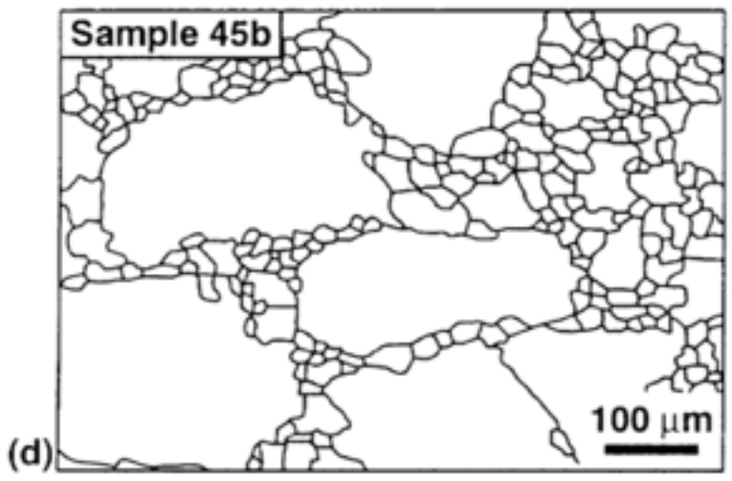
(Carmignani, Conti, et al., 2007)

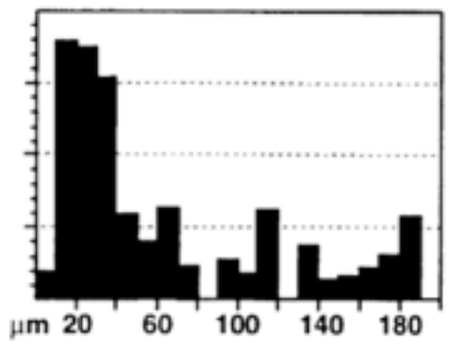
Microstructures in marbles: measure

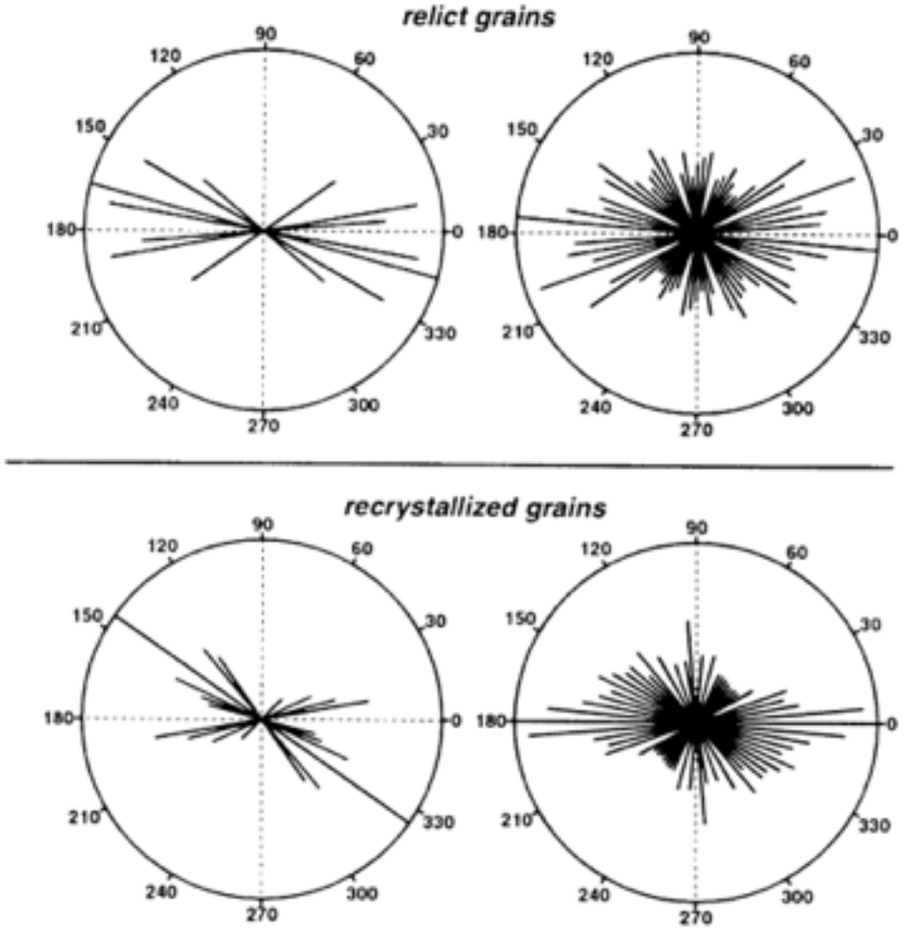








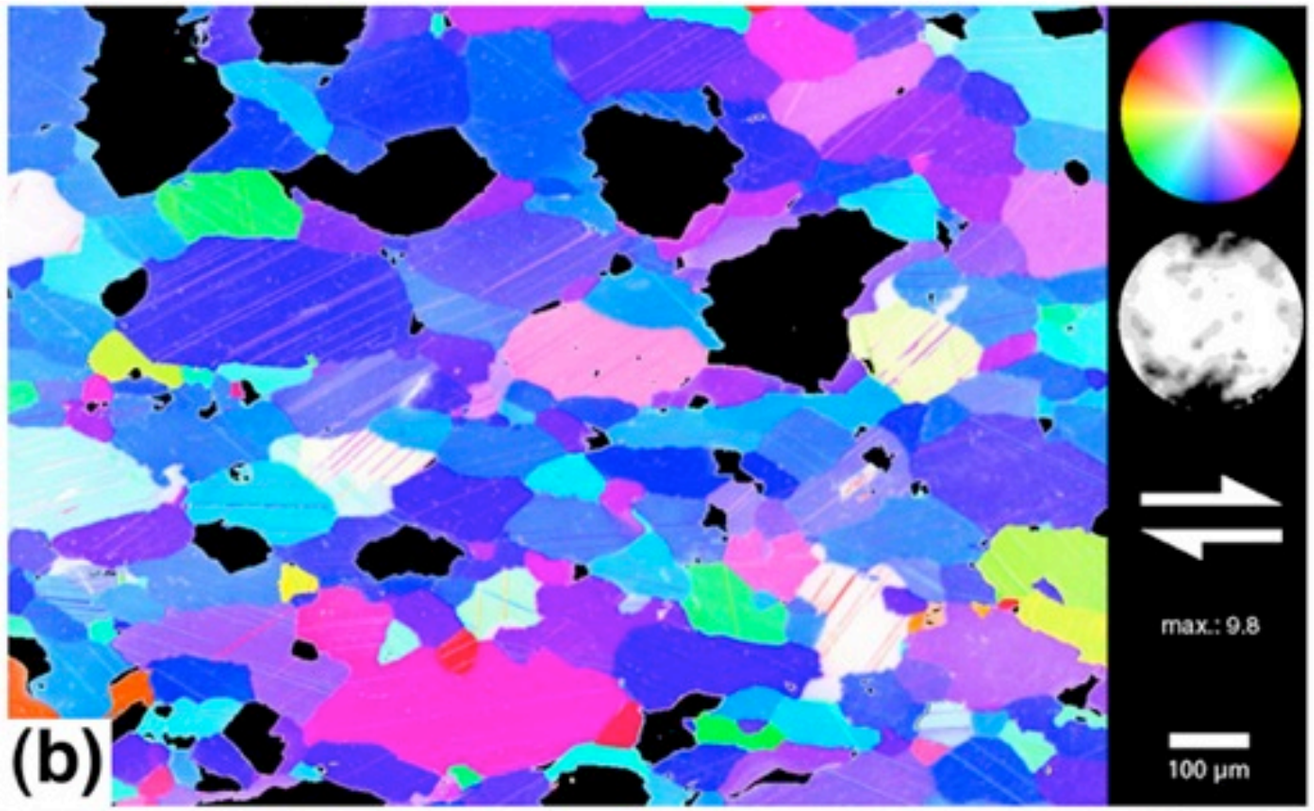


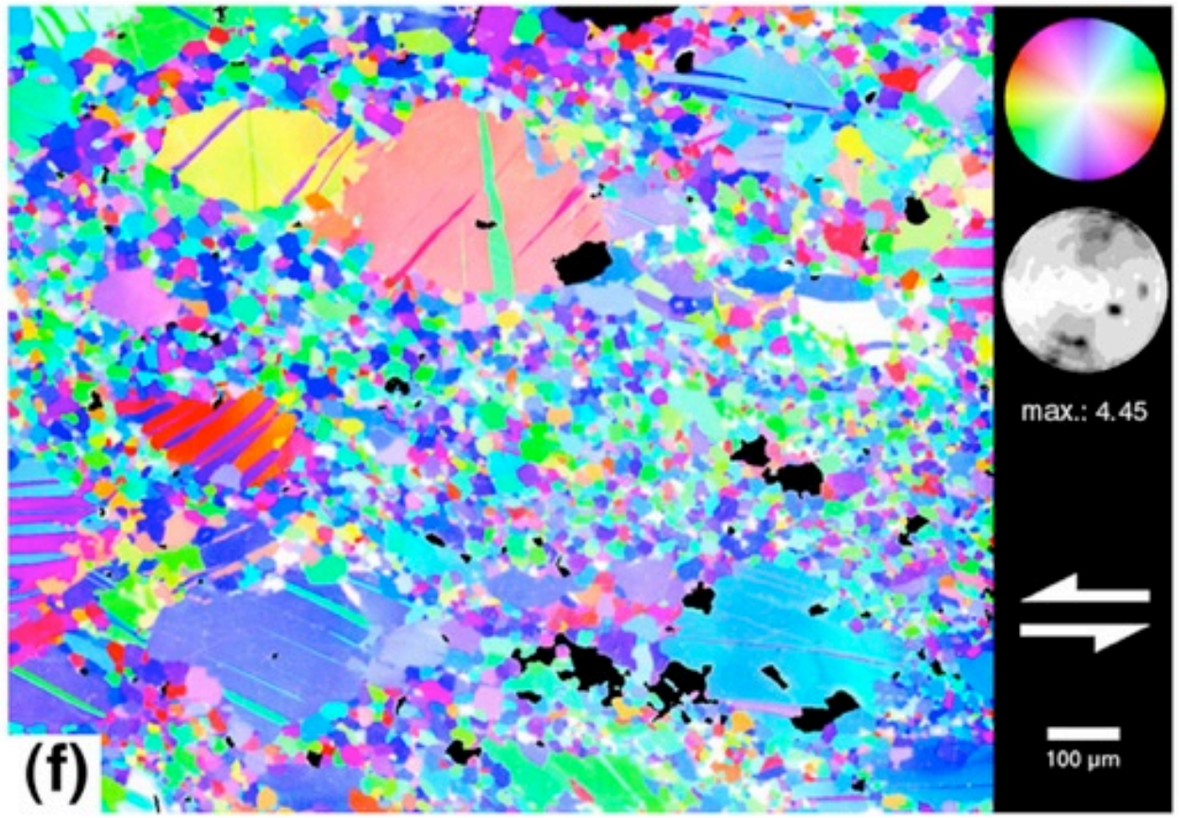


(Molli, Conti et al., 2007)

Textures in marbles: measure

(same color, same crystallographic orientation)





(Molli, Conti et al., 2007)

CIP analysis
(Heilbronner Panozzo R. & Pauli C. (1993) - Integrated spatial and orientation analysis of quartz c-axis by computer-aided microscopy. Journal of Structural Geology, 13, 369–382.)

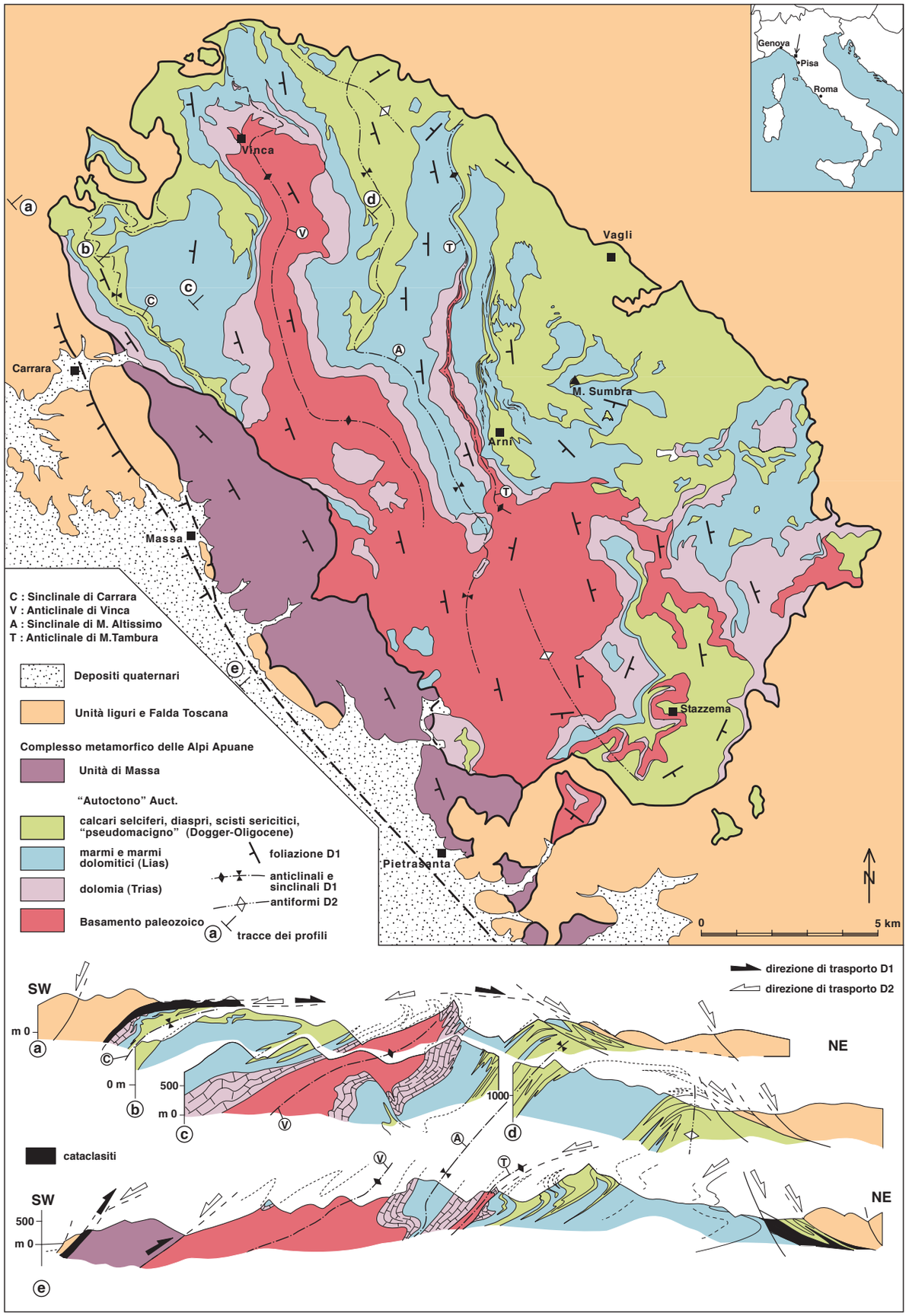
In marble rocks ...

- Physical properties of rock linked with texture and microstructure;
- Laboratory studies yield informations about rock texture and microstructure and therefore inferences about physical properties;
- Development of texture and microstructure related to geological history of rock;
- Field geology and laboratory studies allow to estimate the microstucture and texture expected in an area.

Microstructure, texture and geological evolution

Carrara marble, Alpi Apuane, Italian Northern Apennines

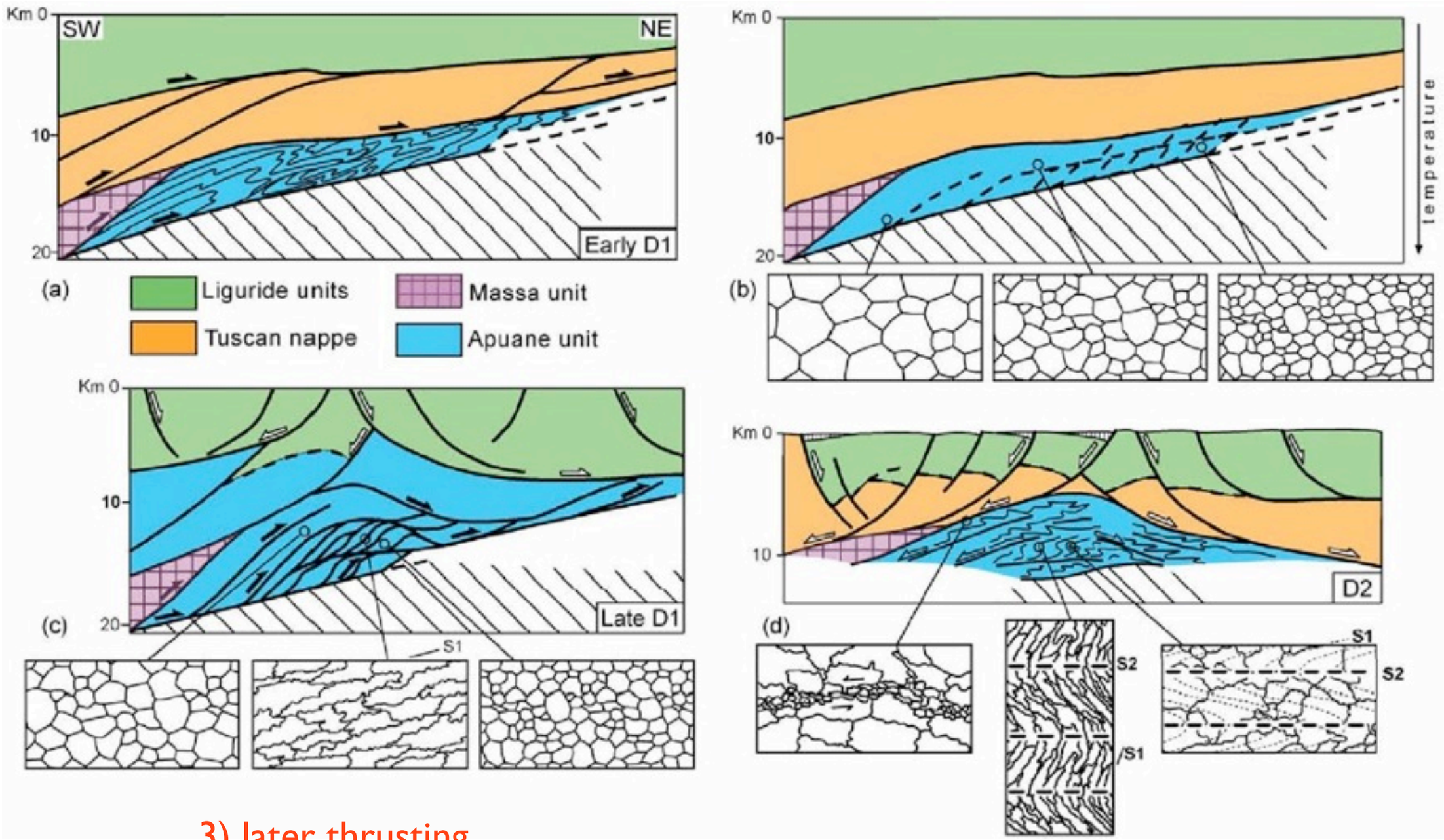
- Alpi Apuane tectonic window
- Jurassic limestones: marbles
- greenschists facies metamorphism during Tertiary



Microstructure, texture and geological evolution

1) subduction, main thrusting, folding

2) metamorphism



3) later thrusting

4) extension, exhumation, normal faulting

Conclusions

- marbles usually are NOT homogeneous rocks;
- marbles are thermally sensitive rocks because calcite anisotropic behaviour, damages at low temperature;
- studies on microstructures and textures in marbles are performed at thin section scale (or even at smaller scale)
- regional and field geology investigations important to link microstructures with tectonic features in the field;
- investigating microstructure and texture in rocks is an appropriate tool for:
  - better set recovery and preservations of marble artifacts;
  - inferences about marble behaviour;
  - evaluation of marble quality.

... evaluation of marble quality ...

- Amoco Corporation Building, Chicago, USA
- Bowing of external marble panels: replacement

Chicago Tribune

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Amoco Chucks All The Marble On Its Tower

March 07, 1989 | By Michael Arndt.

Tweet 0 Share 56 +1 0

Amoco Corp., acknowledging one of the costliest blunders in its 100-year history, said Monday it will strip its headquarters tower of its cherished marble skin and replace the weakening snow-white panels with light-colored granite.

The Chicago-based multinational said the project will cost $60 million to $80 million and take three years.

The 80-story Amoco Building-at 1,136 feet the fourth-tallest building in the world and an integral part of the Chicago skyline-cost less than $120 million to erect only 15 years ago.

Slides, handouts, papers:

www.geotecnologie.unisi.it/conti

conti@unisi.it