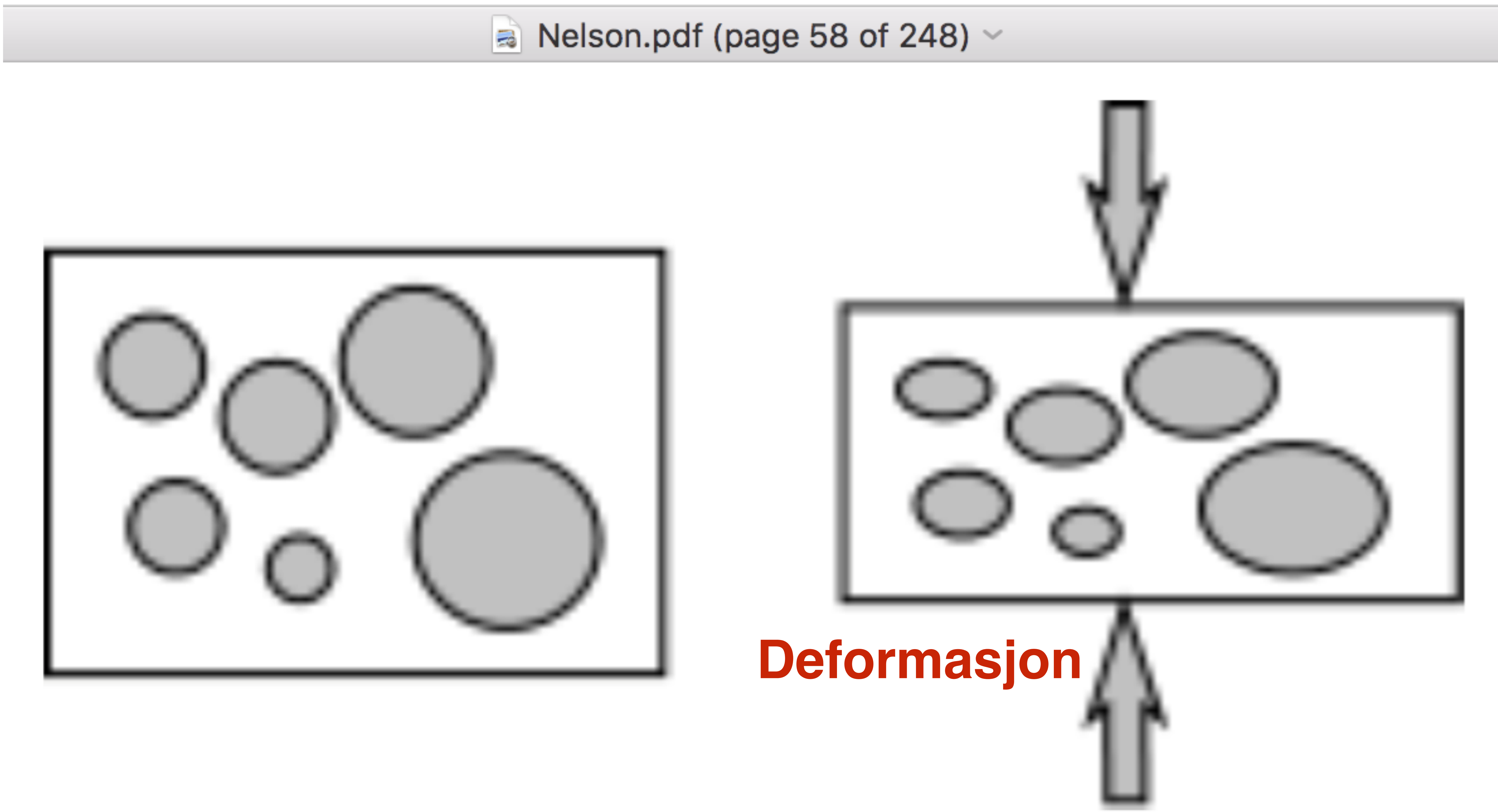
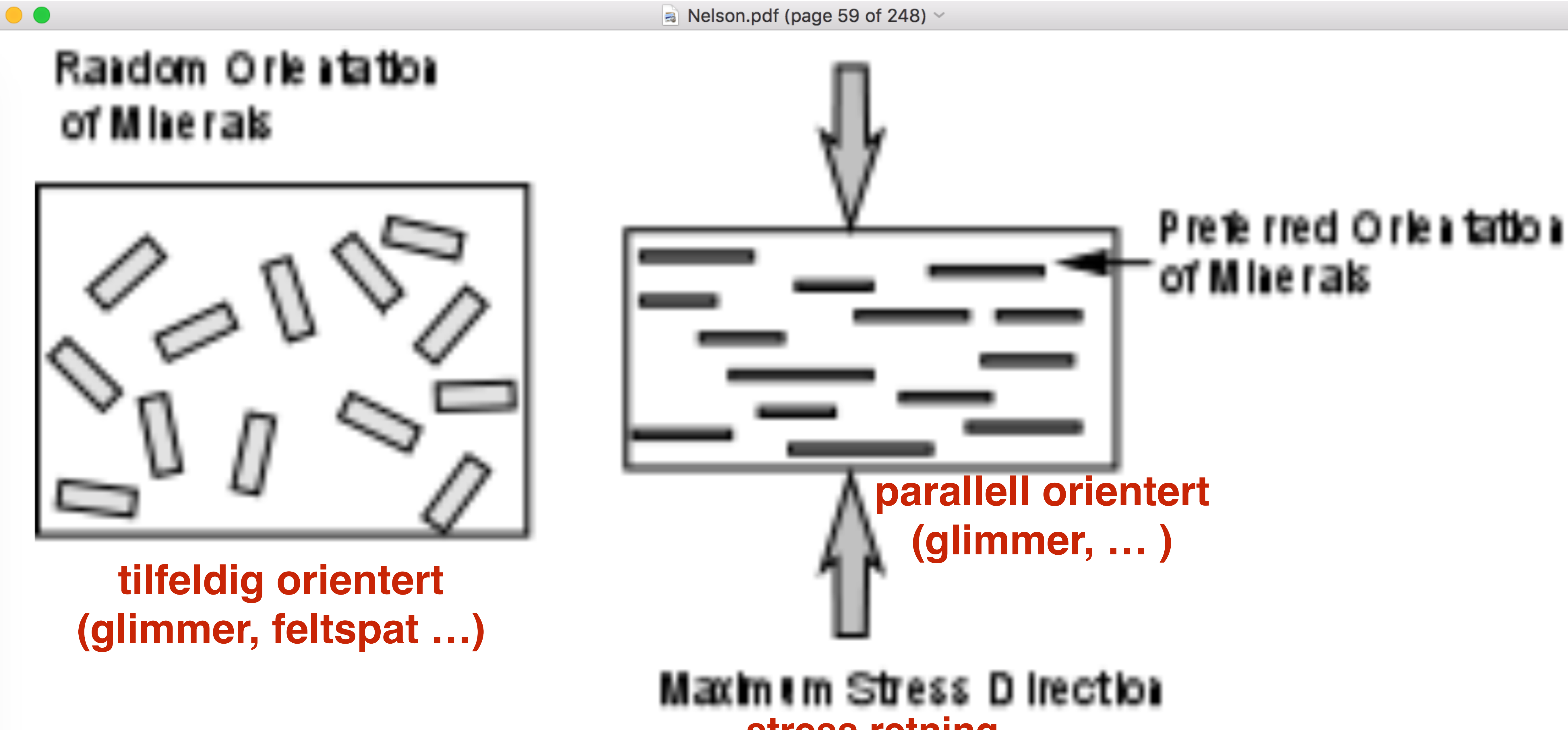
Metamorfose foregår samtidig som *Deformasjon*



Metamorf vekst av mineraler



tilfeldig orientert
(glimmer, feltspat ...)

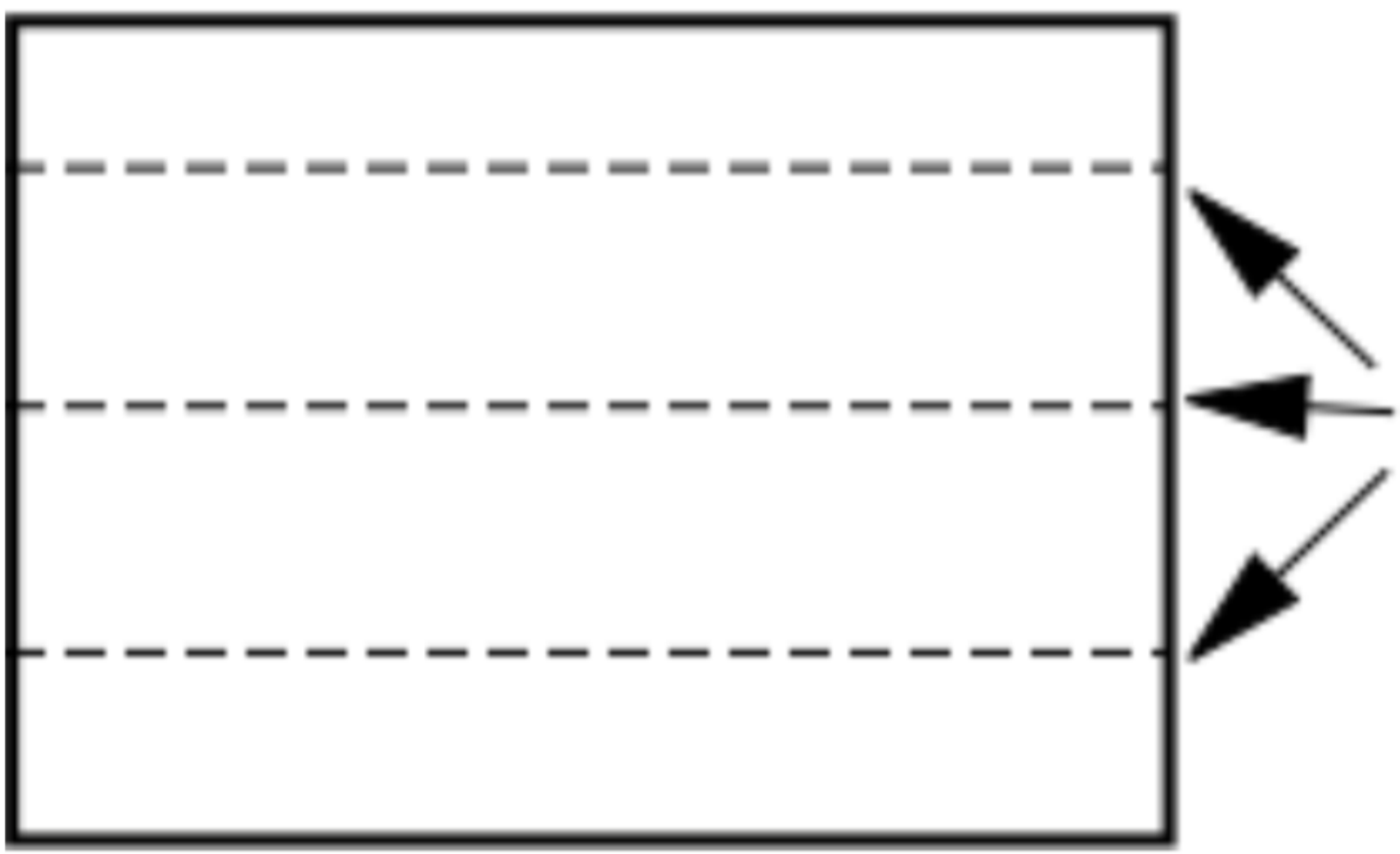
parallell orientert
(glimmer, ...)

stress retning

Tidligere mineraler som er tilfeldig orienterte blir ustabile.
De roterer eller forsvinner.
Nye mineraler vokser, orientert i forhold
til deformasjon og stressretning

Nelson.pdf (page 61 of 248)

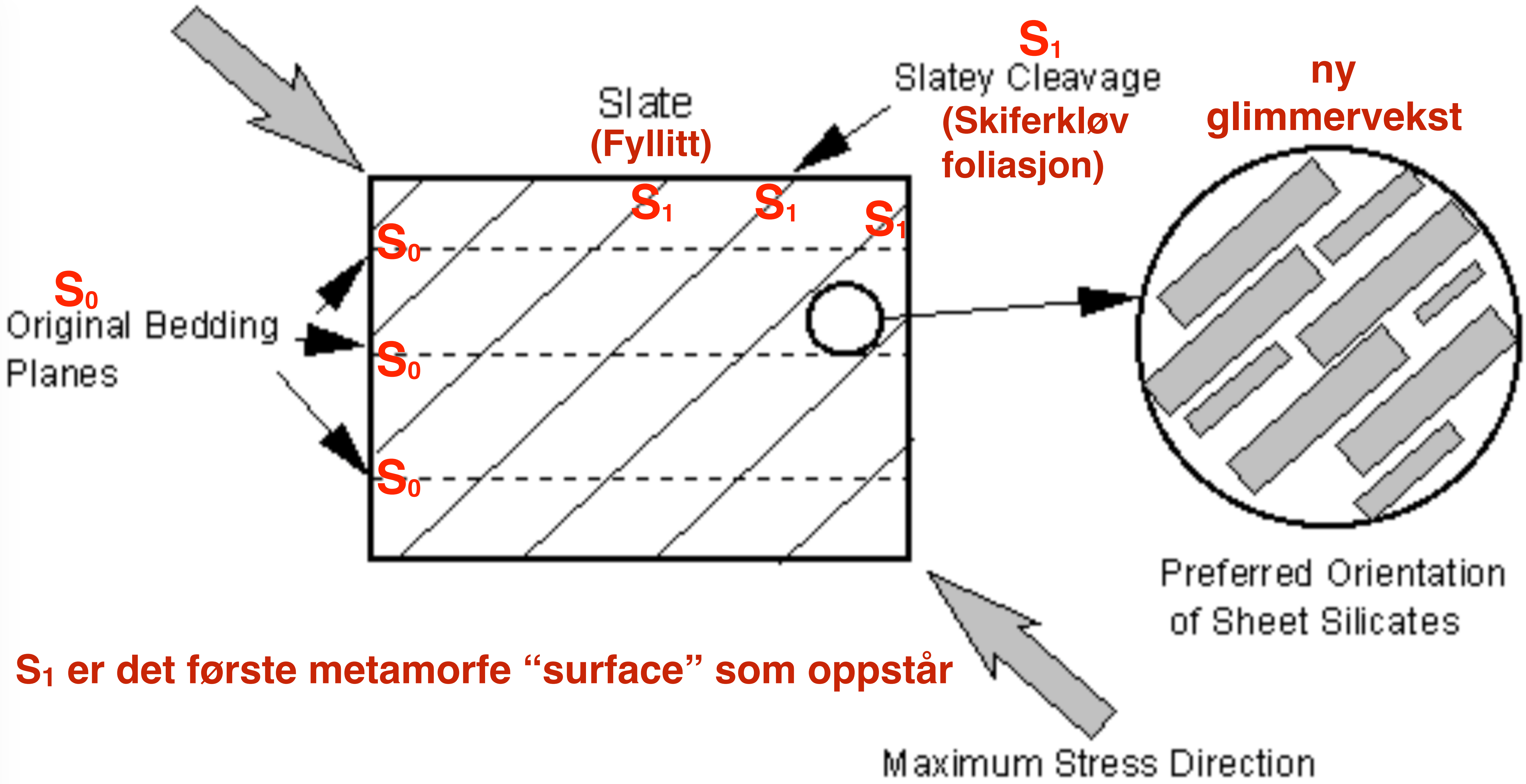
Original Shale **(leirskifer)**



Original Bedding Planes

sedimentær lagning, S_0

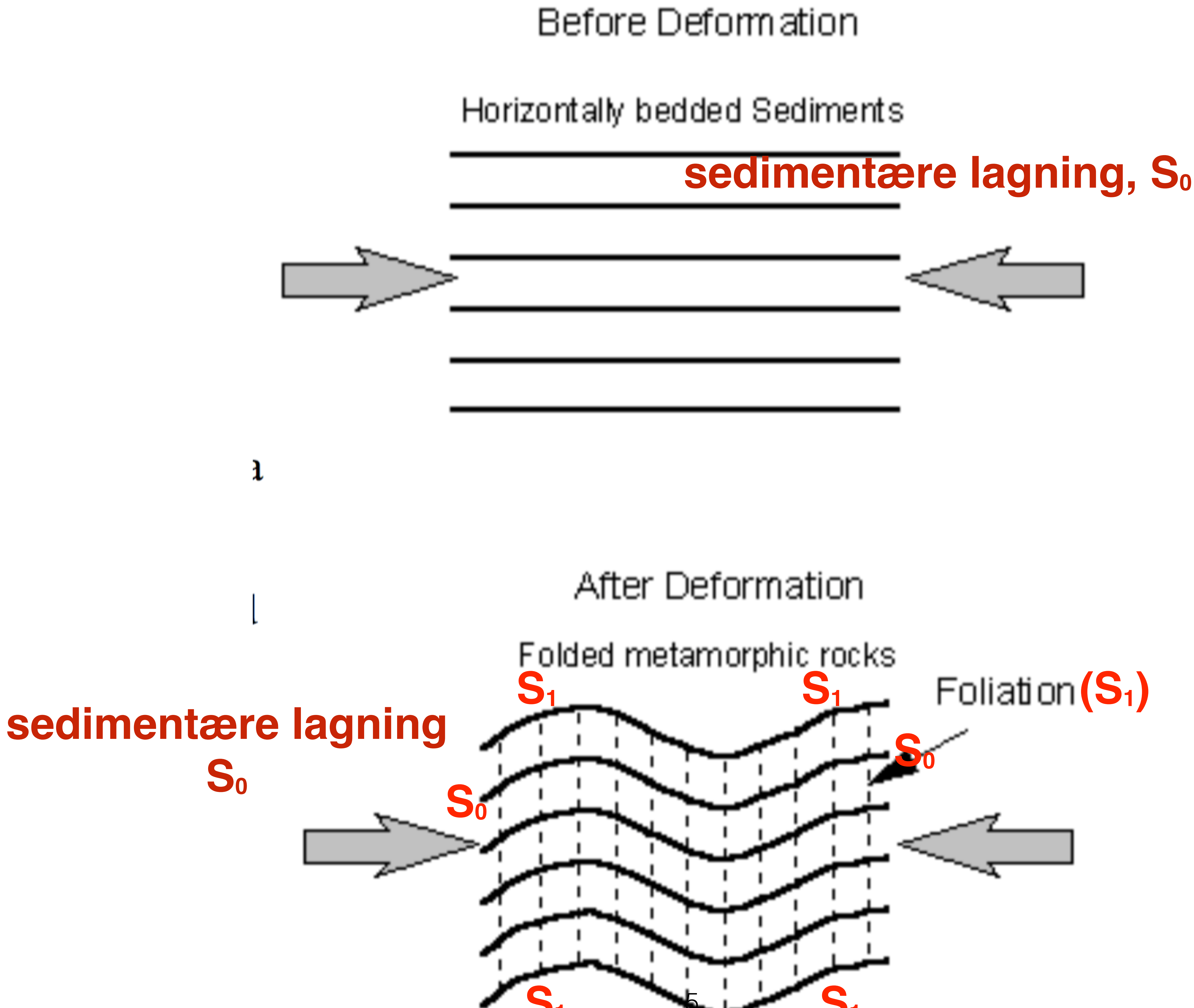
“S” står for “surface” (eller plan)
S_0 er opprinnelig surface

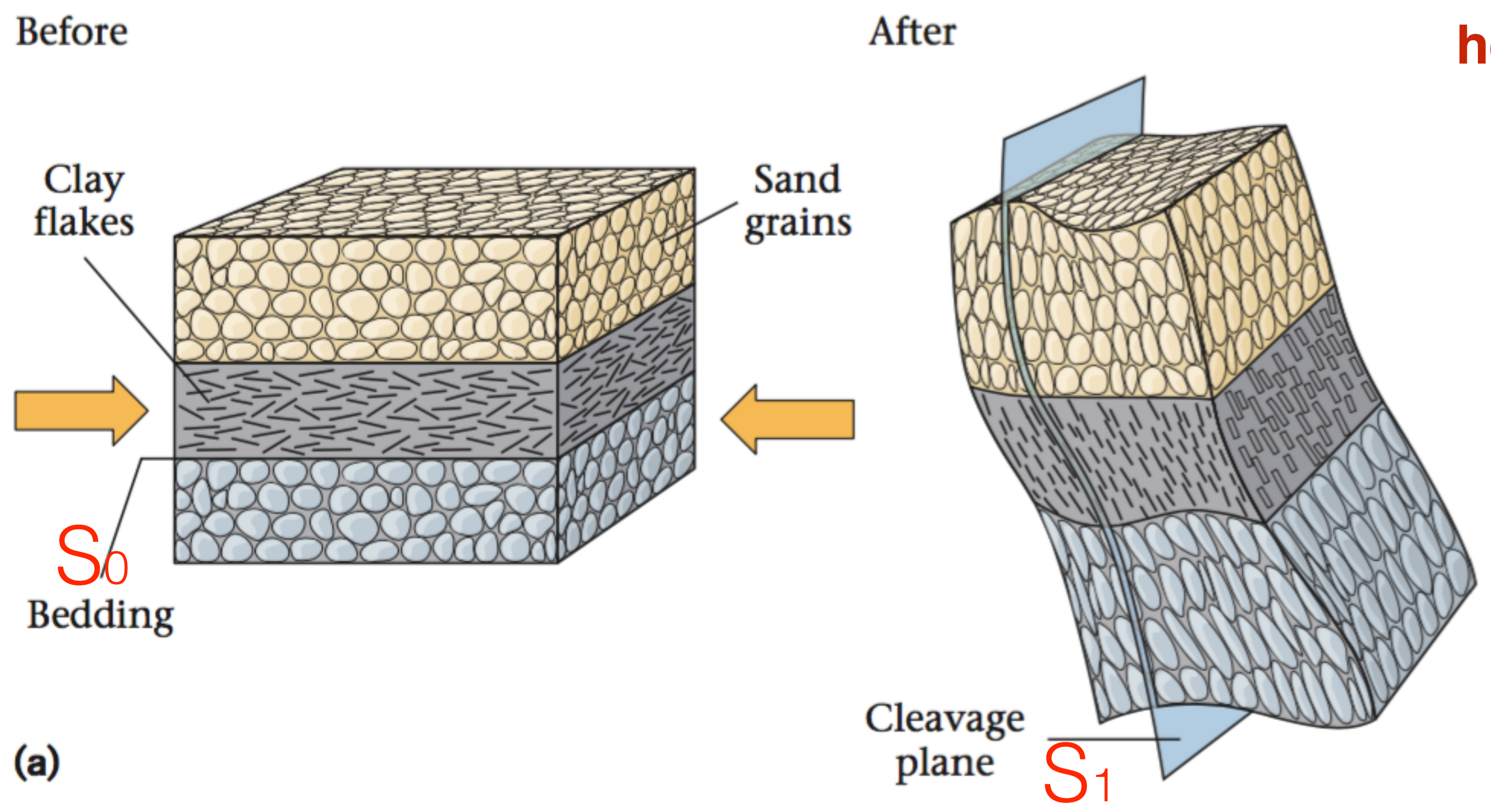


S_1 er det første metamorfe “surface” som oppstår

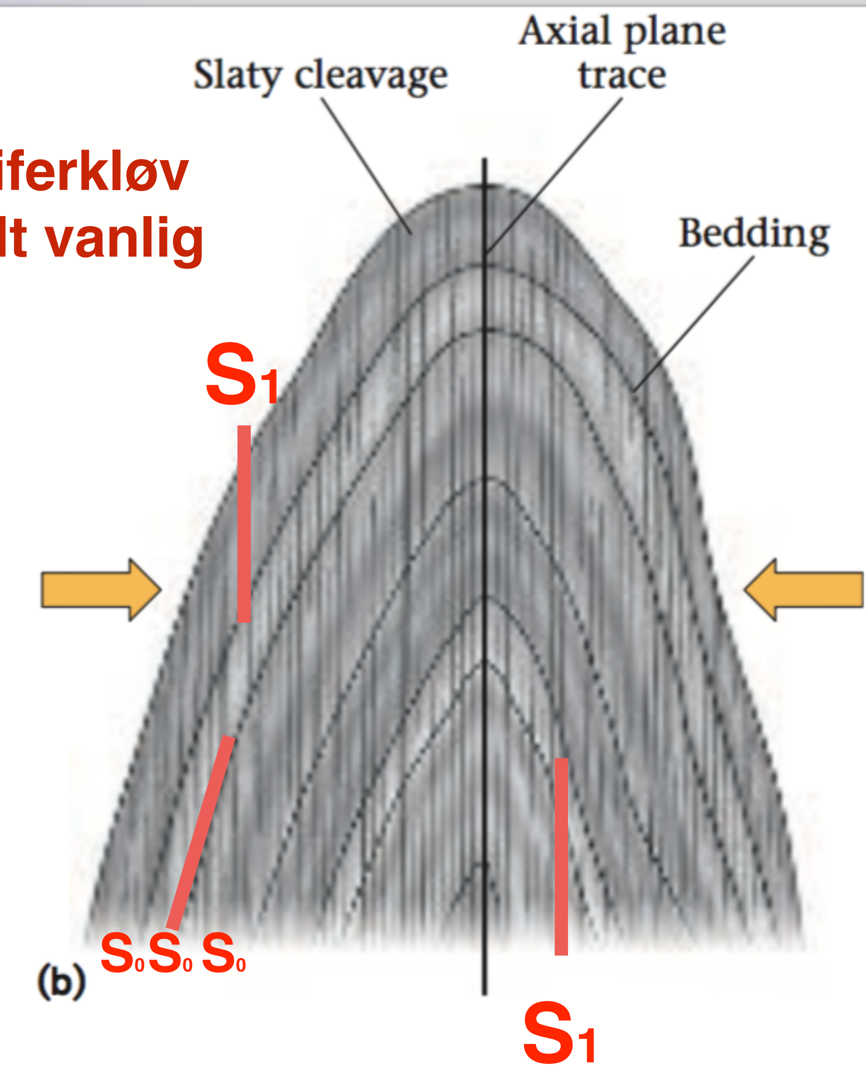
(glimmer vokser i retning som er vinkelrett til maksimal stress)
(minste motstands retning)

Nelson.pdf (page 65 of 248)



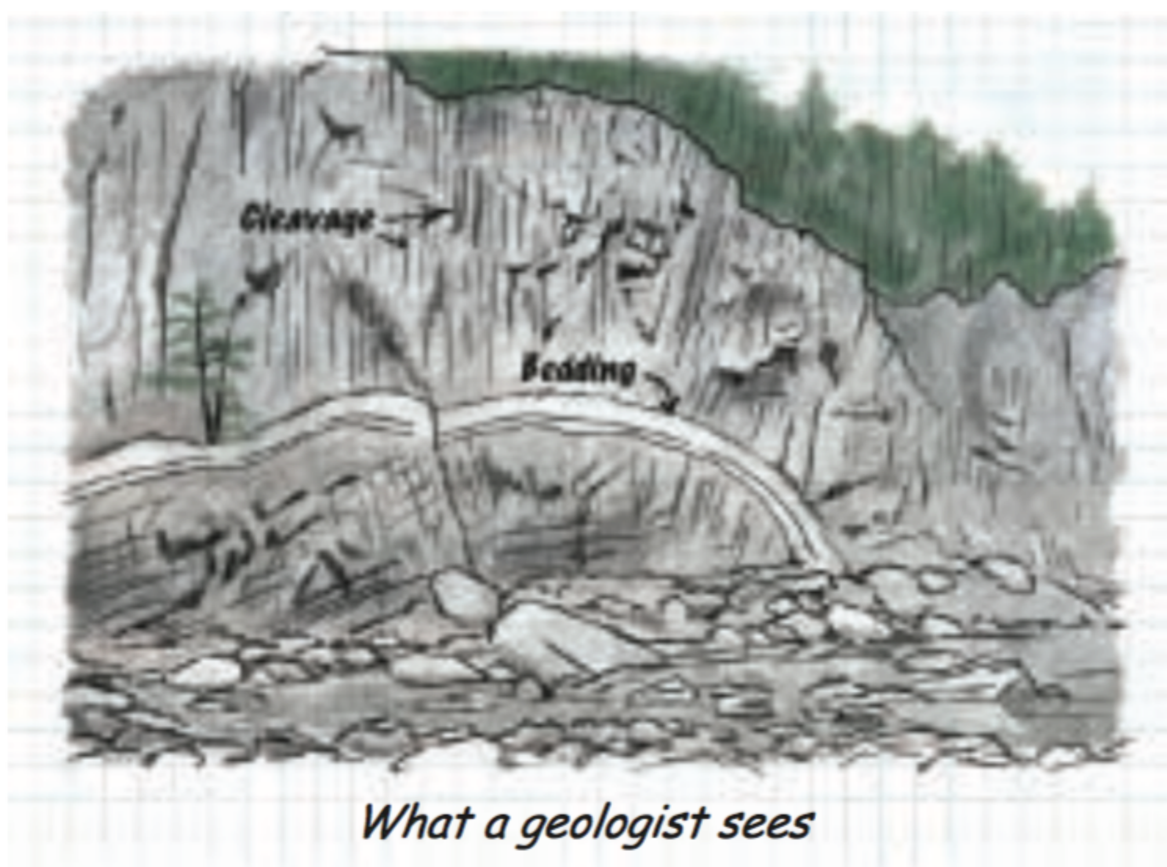

Before
After
Clay
flakes
Sand
grains
S0
Bedding
Cleavage
plane
S1

(a)


Slaty cleavage
Axial plane
trace
skiferkløv
helt vanlig
Bedding
S1
S0 S0 S0
S1

(b)

(c)


Cleavage
Bedding
What a geologist sees

(d)

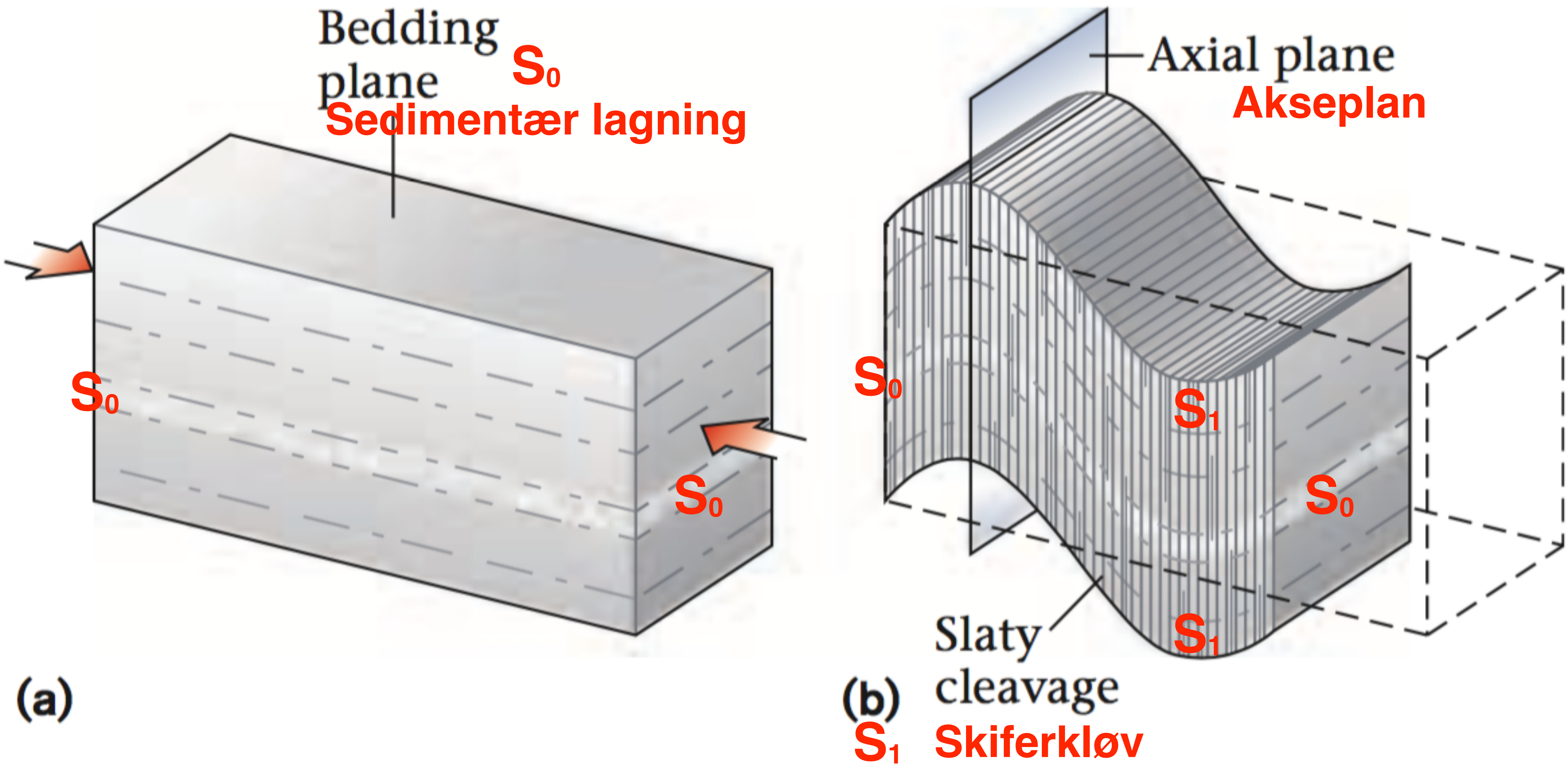
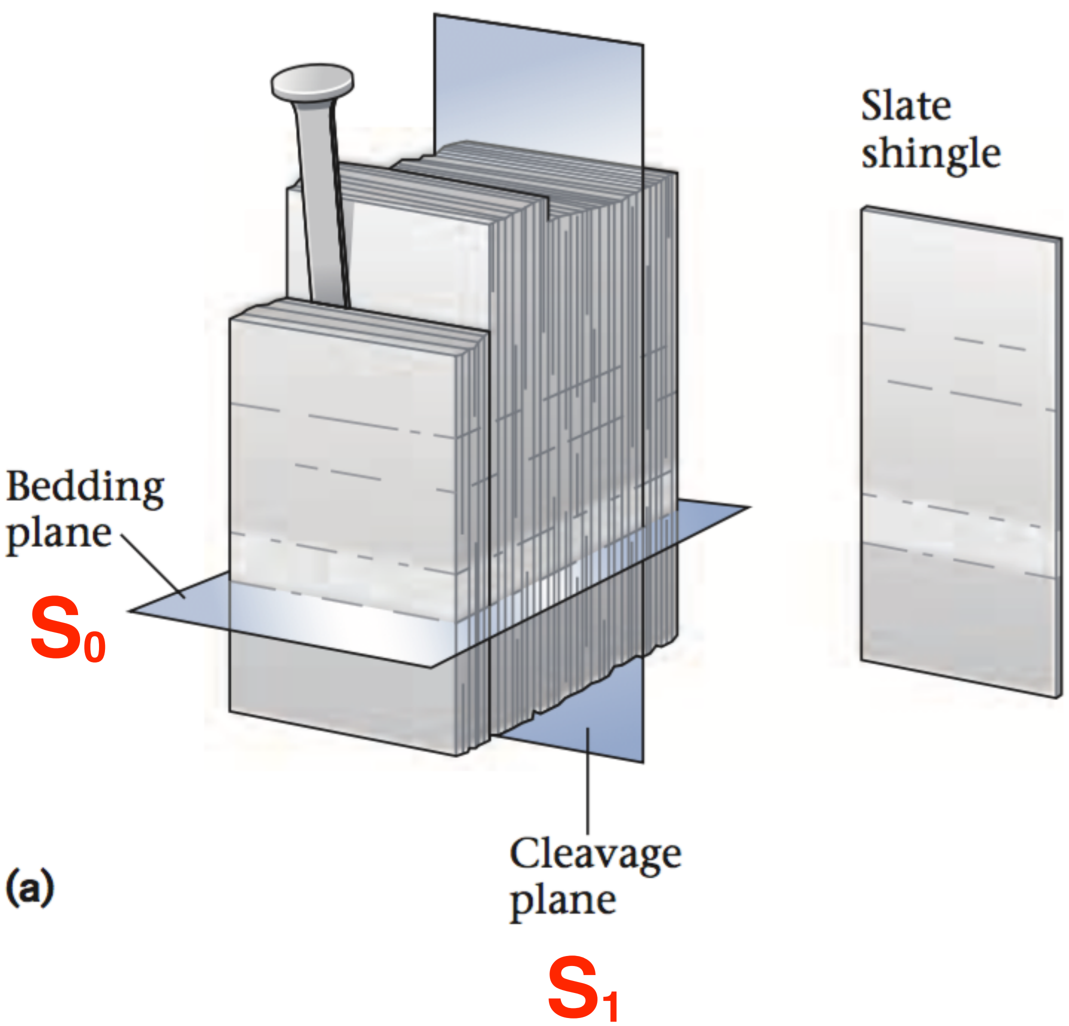


FIGURE 8.9 **(a)** The end-on compression of a bed will create slaty cleavage at an angle perpendicular to the bedding. **(b)** Commonly, the rock folds (bends into curves) at the same time cleavage forms. Cleavage tends to be parallel to the axial plane of the fold, the imaginary plane that divides the fold in half (see Chapter 11). The dashed lines indicate the original shape of the rock body that was deformed.

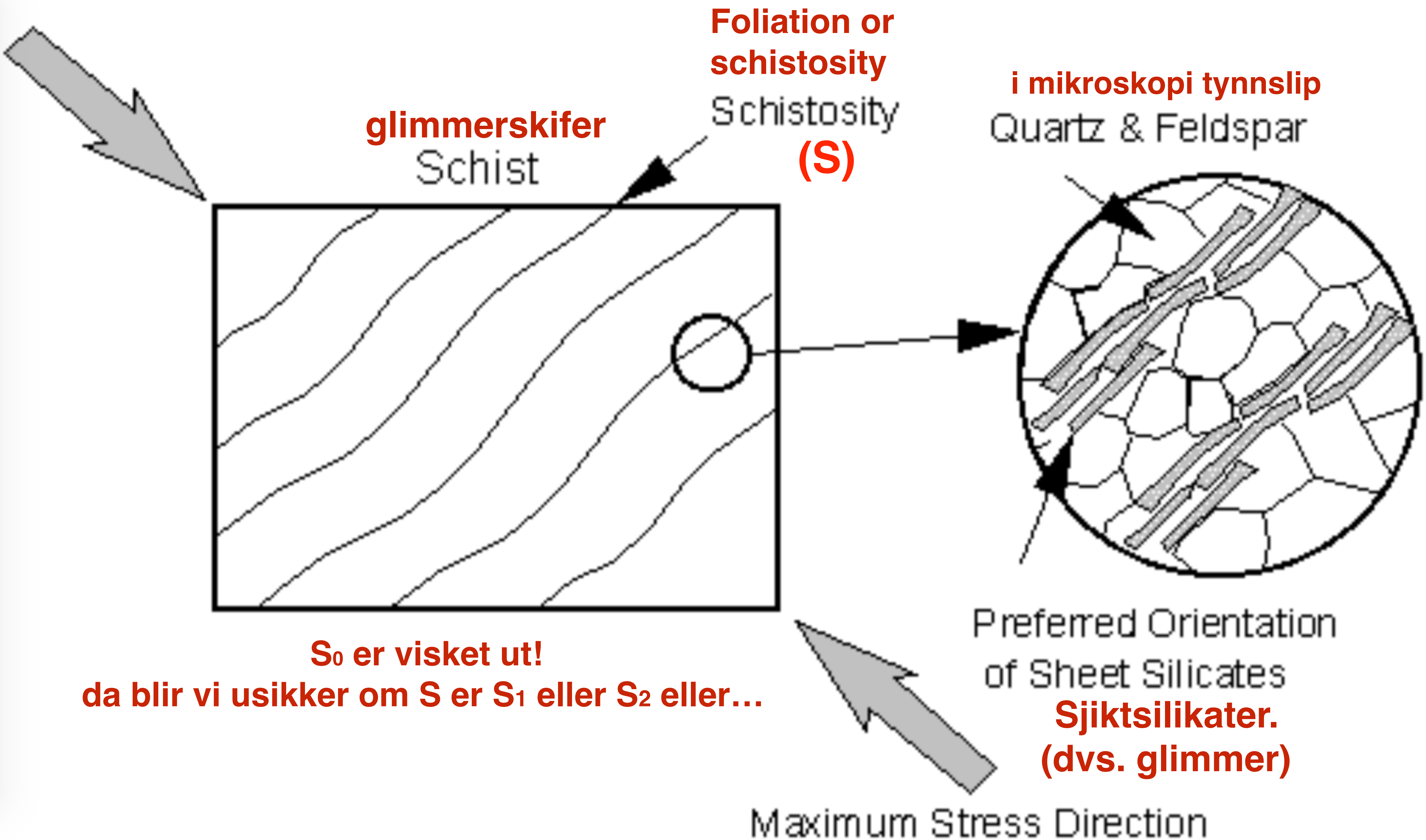
FIGURE 8.8 **(a)** A block of rock with slaty cleavage splits along cleavage planes into thin sheets. Originally, the slate was shale and had sedimentary bedding. If you look carefully, you may find hints of the bedding, indicated by sandier layers, in the slate. Note that in this example, the bedding plane and cleavage plane are not parallel. **(b)** Slate easily splits into thin sheets that can be used as shingles on roofs. Here, an old-style shingle maker in Wales plies his trade. **(c)** A slate roof.



(a)

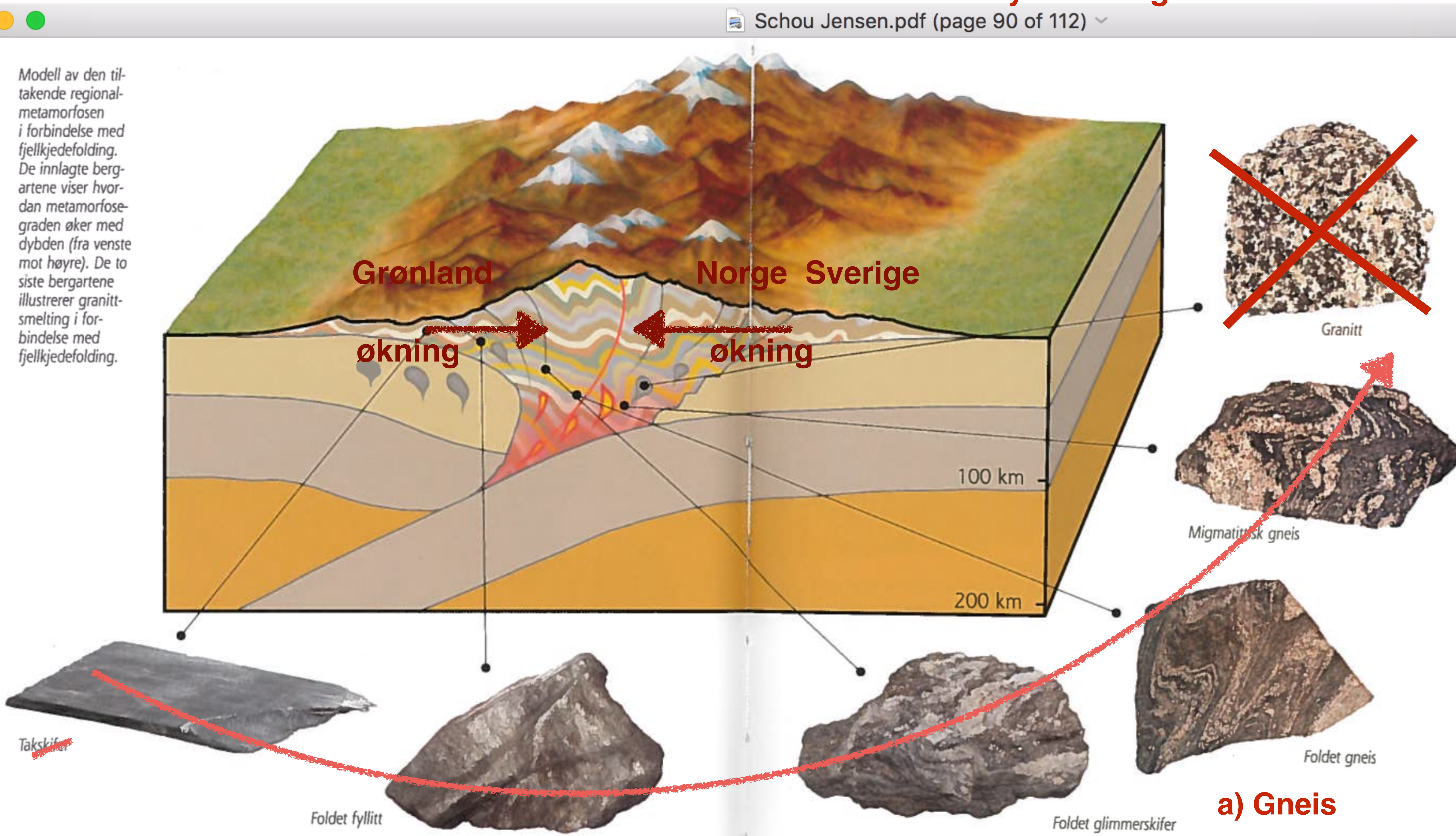
(b)

Nelson.pdf (page 62 of 248)



Mye av Norge er GNEISER

Modell av den tiltakende regionalmetamorfosen i forbindelse med fjellkjedefolding. De innlagte bergartene viser hvordan metamorfosegraden øker med dybden (fra venste mot høyre). De to siste bergartene illustrerer granittsmelting i forbindelse med fjellkjedefolding.



a) Gneis

d) Gneis

a) Leirskifer

d) Granitt

a) Fyllitt

d) Granitt

a) Glimmerskifer

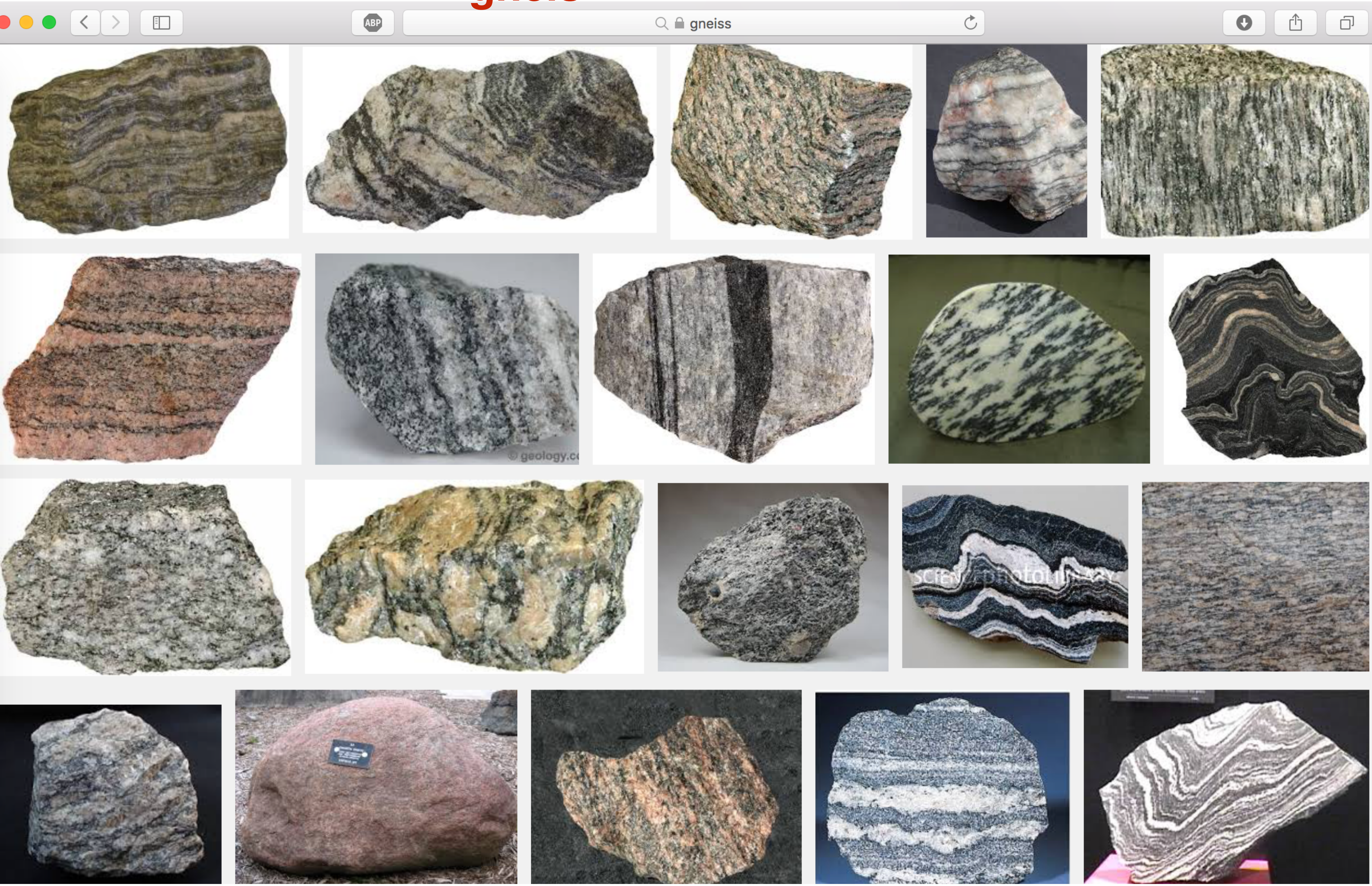
d) Gneis

Mye av Norge er GNEIS

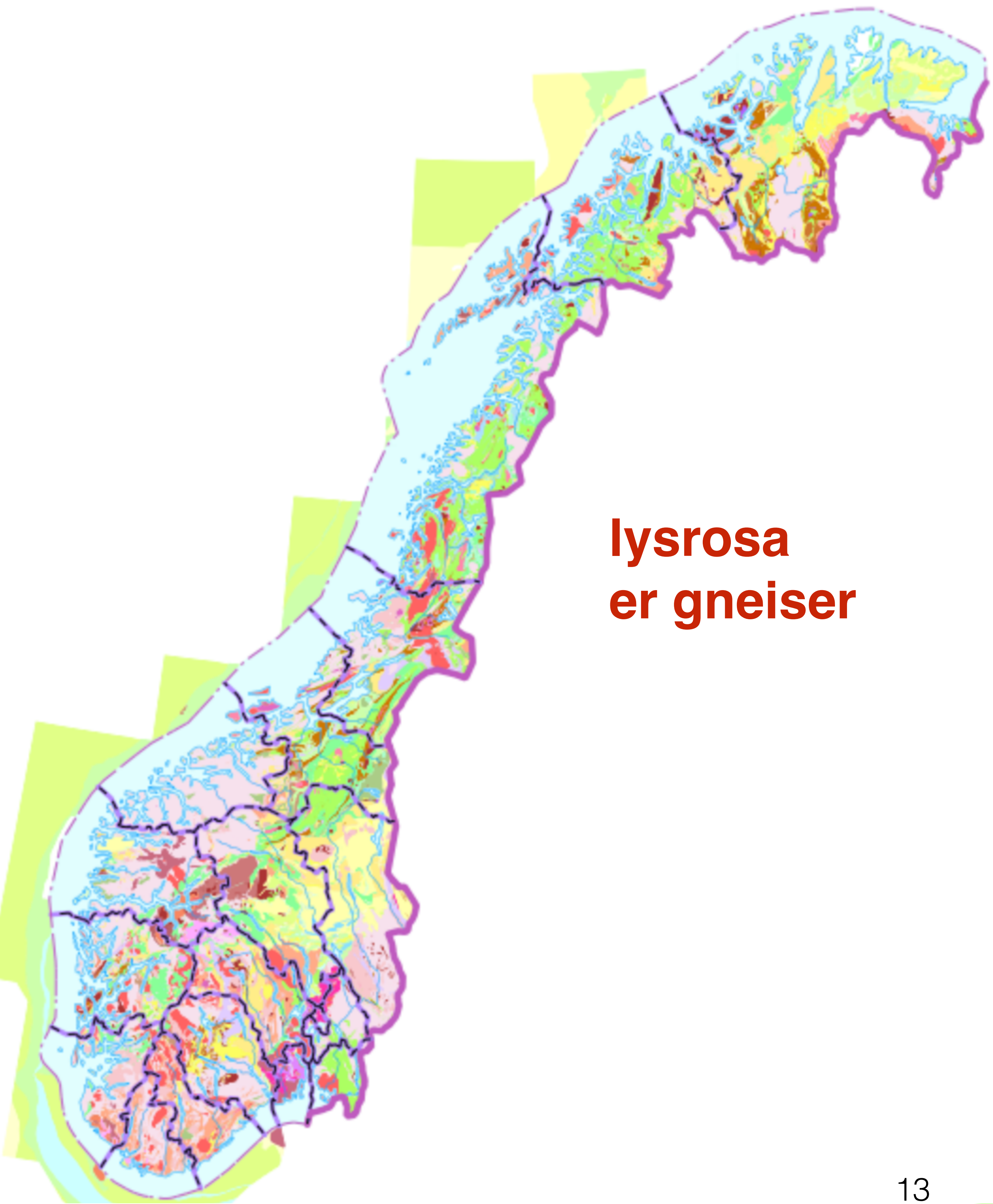
Migmatittisk gneis (Moss). De lyse slirene i gneisen er dannet i forbindelse med begynnende oppsmelting av bergarten, der kvarts og feltspat, som har lavere smeltepunkt, er blitt mobile i motsetning til de mørke mineralene – omvendt av Bowens reaksjonsskjema (se side 96–97).

kvarts og feltspat
(Typisk partiell smelte har ca.: 1/3 kvarts, 1/3 plagioklas, 1/3 kalifeltspat
Kalles for "minimum-temperatur smeltesammensetning")

gneis



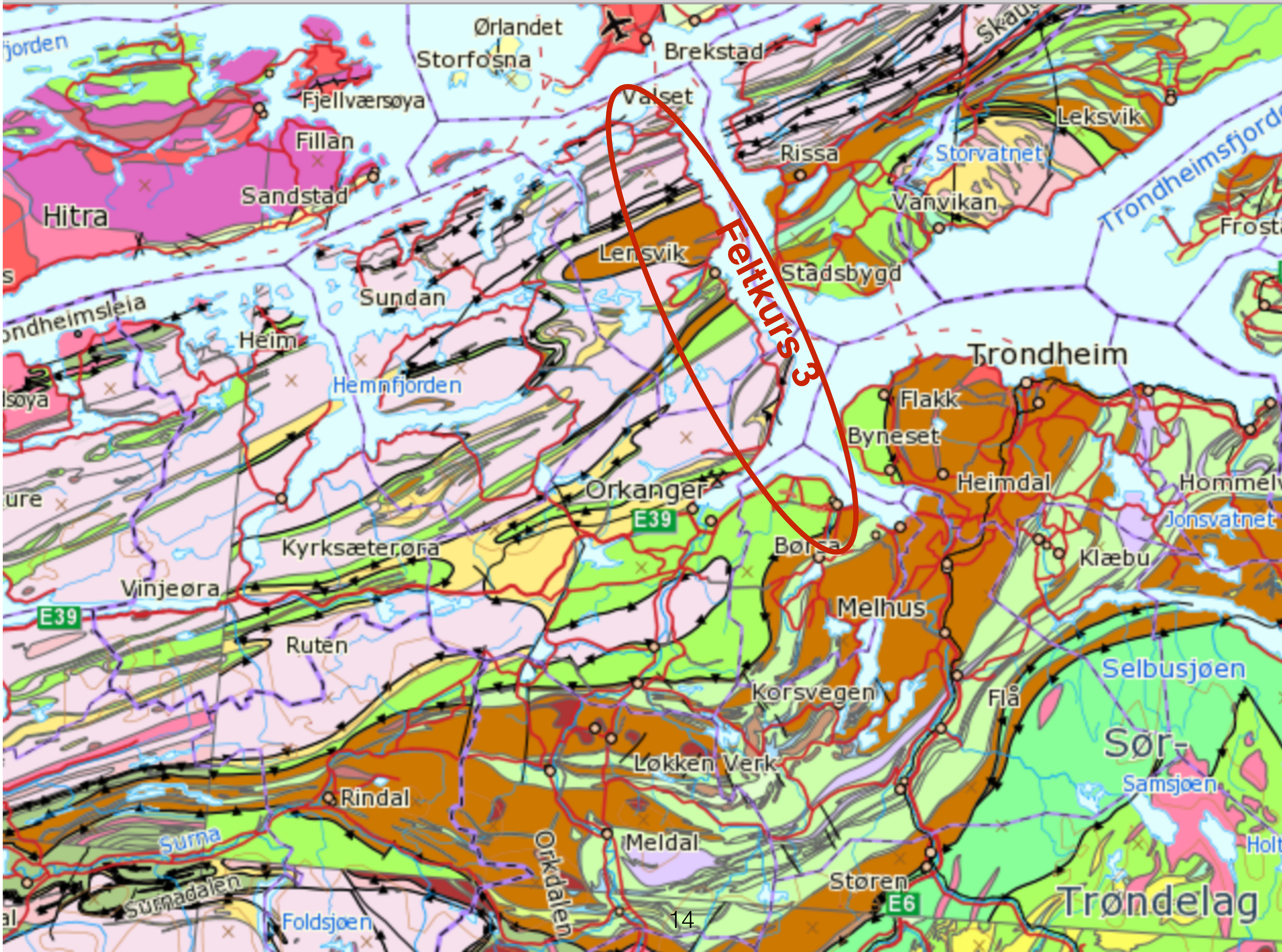
geo.ngu.no/kart/berggrunn/



lysrosa
er gneiser

lysrosa er gneis

geo.ngu.no/kart/berggrunn/



Hvordan oppstår lagdeling i gneiser?

2 helt ulike prosesser

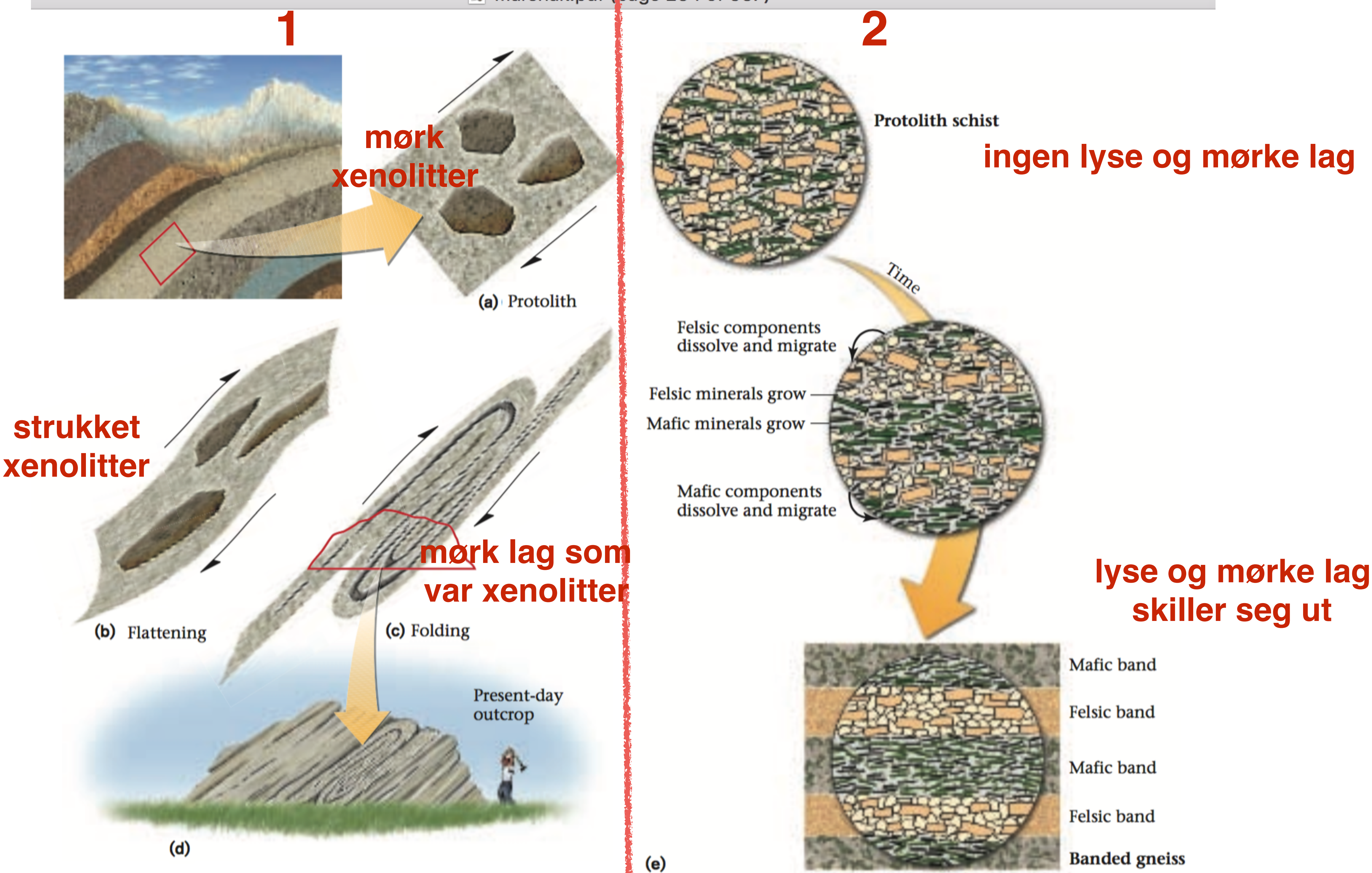
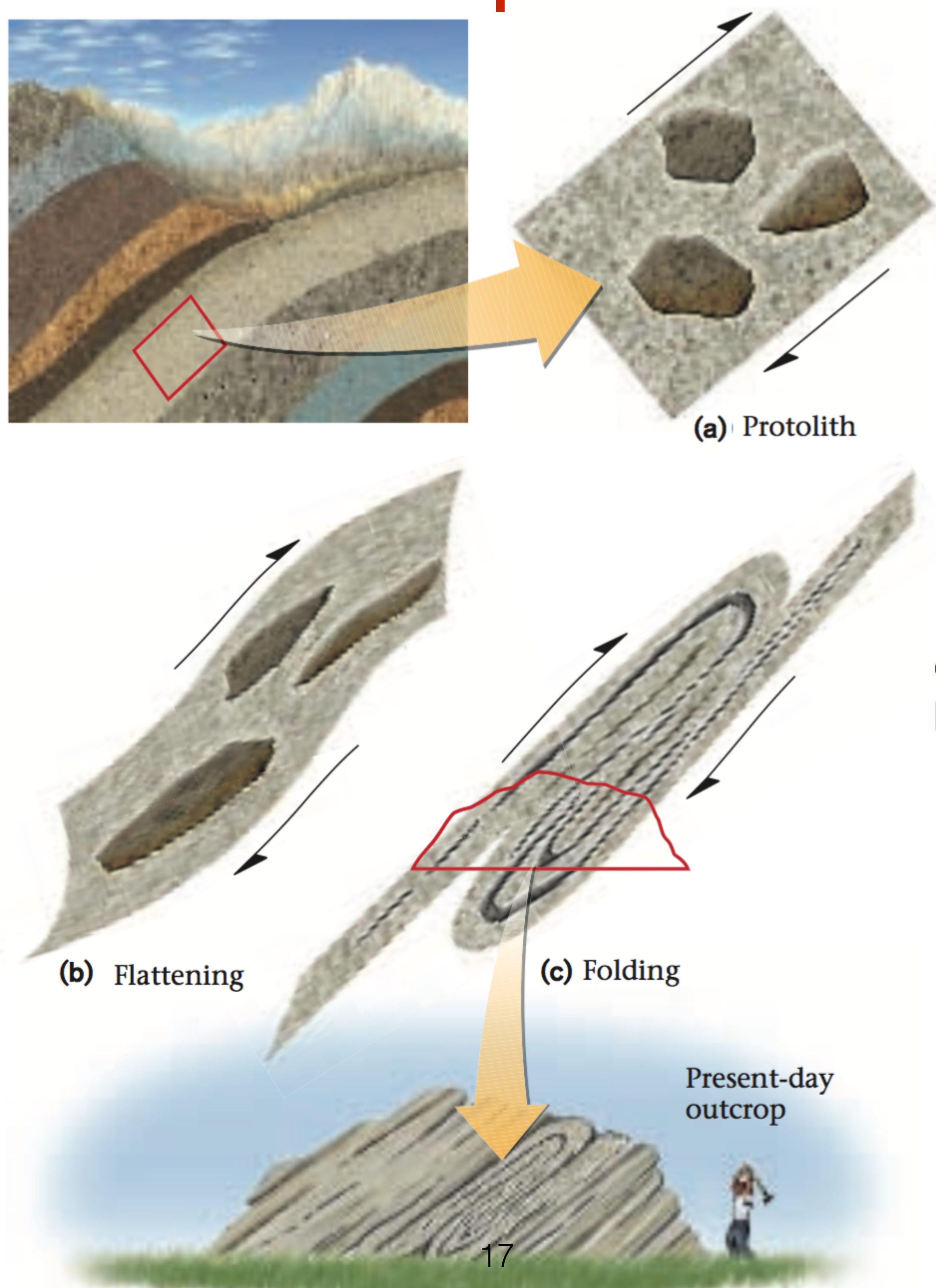


FIGURE 8.12 A schematic model illustrating one of the ways in which gneissic banding forms. **(a)** The protolith, in this case an intrusive igneous rock, contains patches that are more mafic than the surrounding felsic rock. **(b)** Shear stretches and flattens the rock. The mafic patches stretch and flatten too. While this is happening, recrystallization and neocrystallization are taking place throughout the rock, and a preferred mineral orientation develops. **(c)** The layer is folded back on itself in response to continued shear. **(d)** A present-day outcrop of this rock displays mafic bands separated by felsic bands. **(e)** During metamorphic differentiation, felsic minerals dissolve in mafic layers and grow in felsic layers, while mafic minerals dissolve in felsic layers and grow in mafic layers.

1

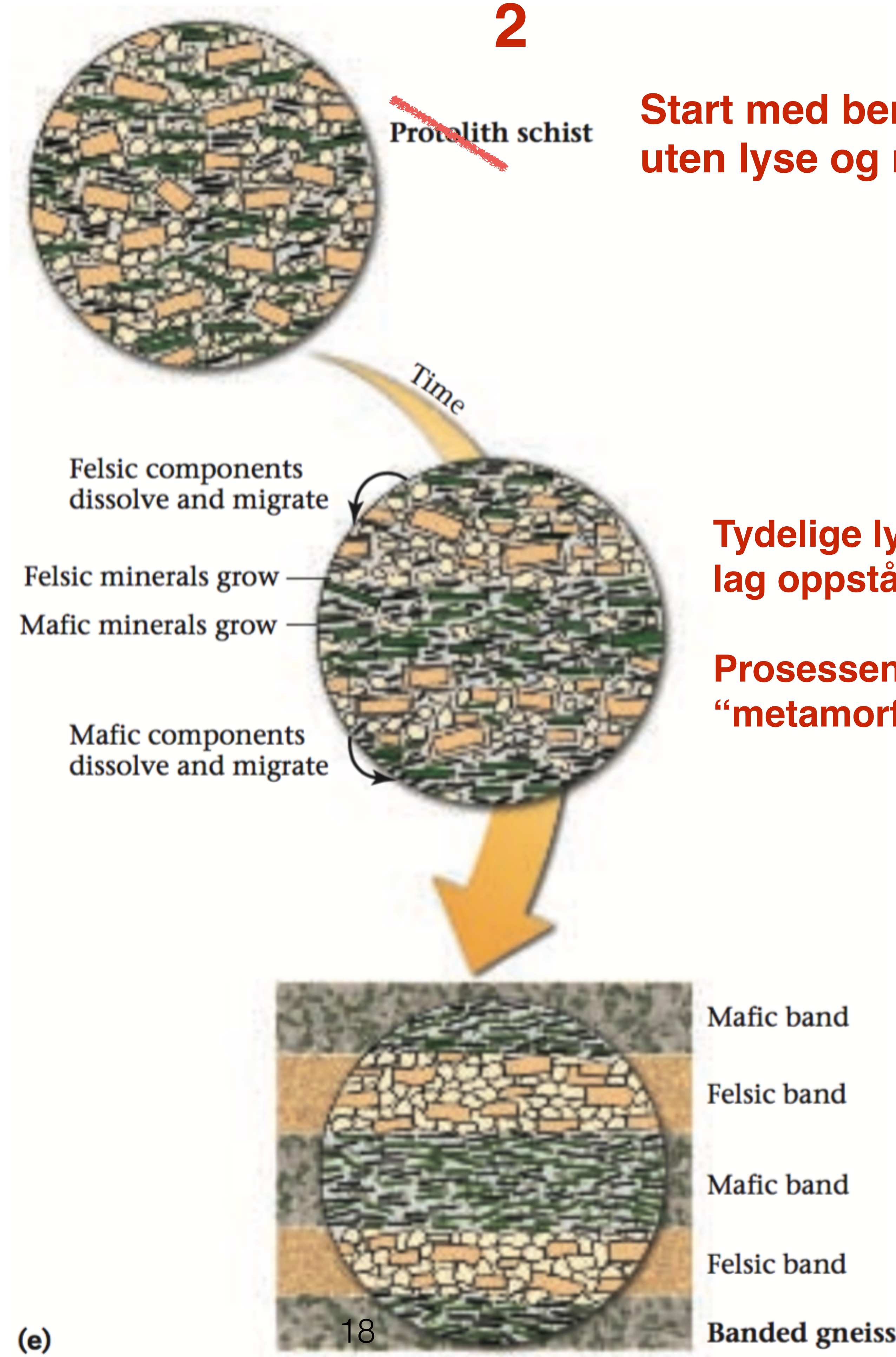


Opprinnelige xenolitter blir presset flatt.

Marshak.pdf (page 264 of 957)

2

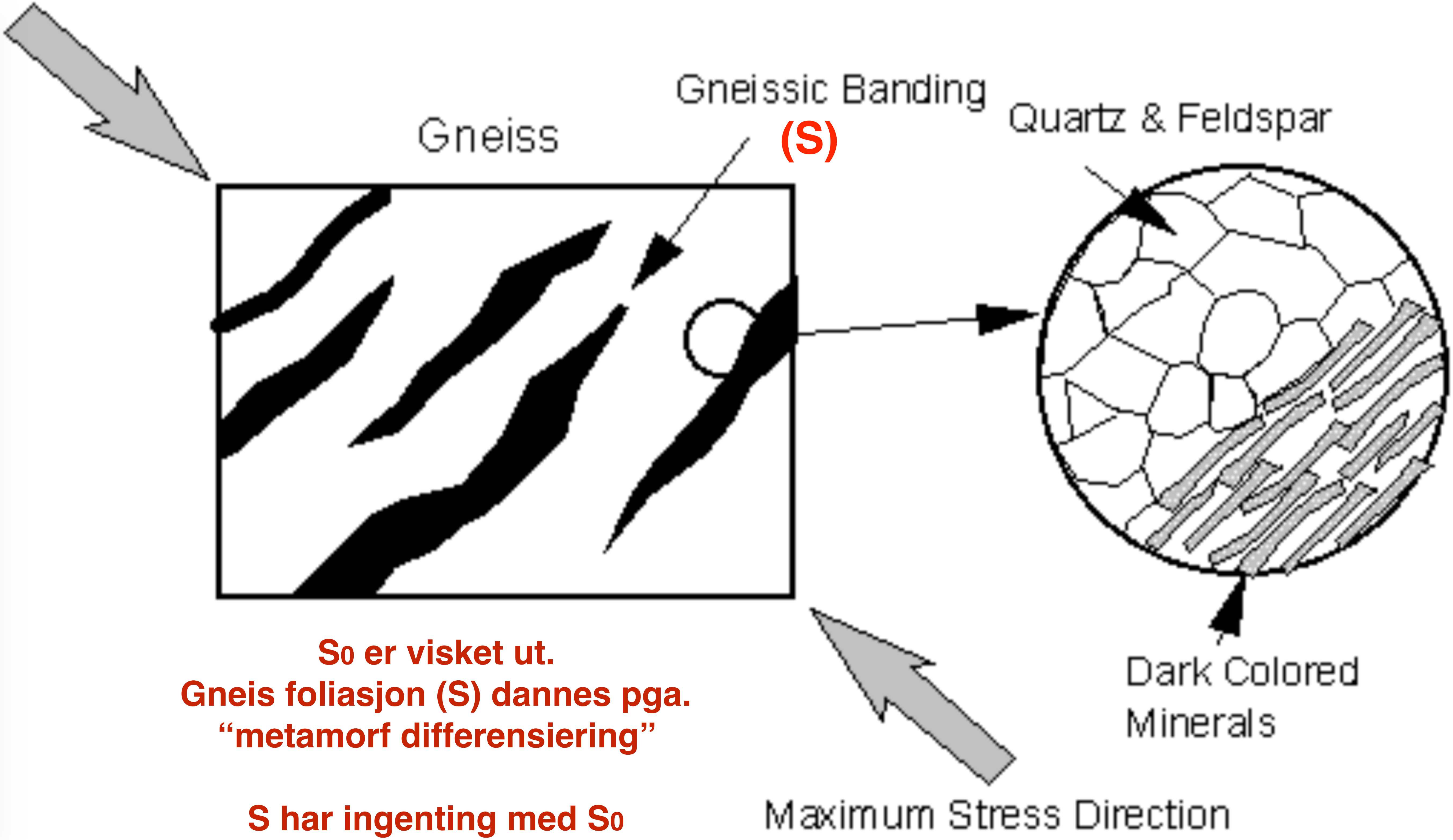
Start med bergart
uten lyse og mørke lag.



(e)

Tydelige lyse og mørke
lag oppstår under metarmofose.

Prosessen heter
“metamorf differensiering”



S_0 er visket ut.
Gneis foliasjon (S) dannes pga.
“metamorf differensiering”

S har ingenting med S_0
å gjøre

hjemmevideo: regnvann på gata, Ila, Trondheim

vann organsierer seg i pulser (bølger, soner)
slik som lyse og mørke mineraler gjør

hjemmevideo: regn på gata, Ila, Trondheim

Marshak.pdf (page 269

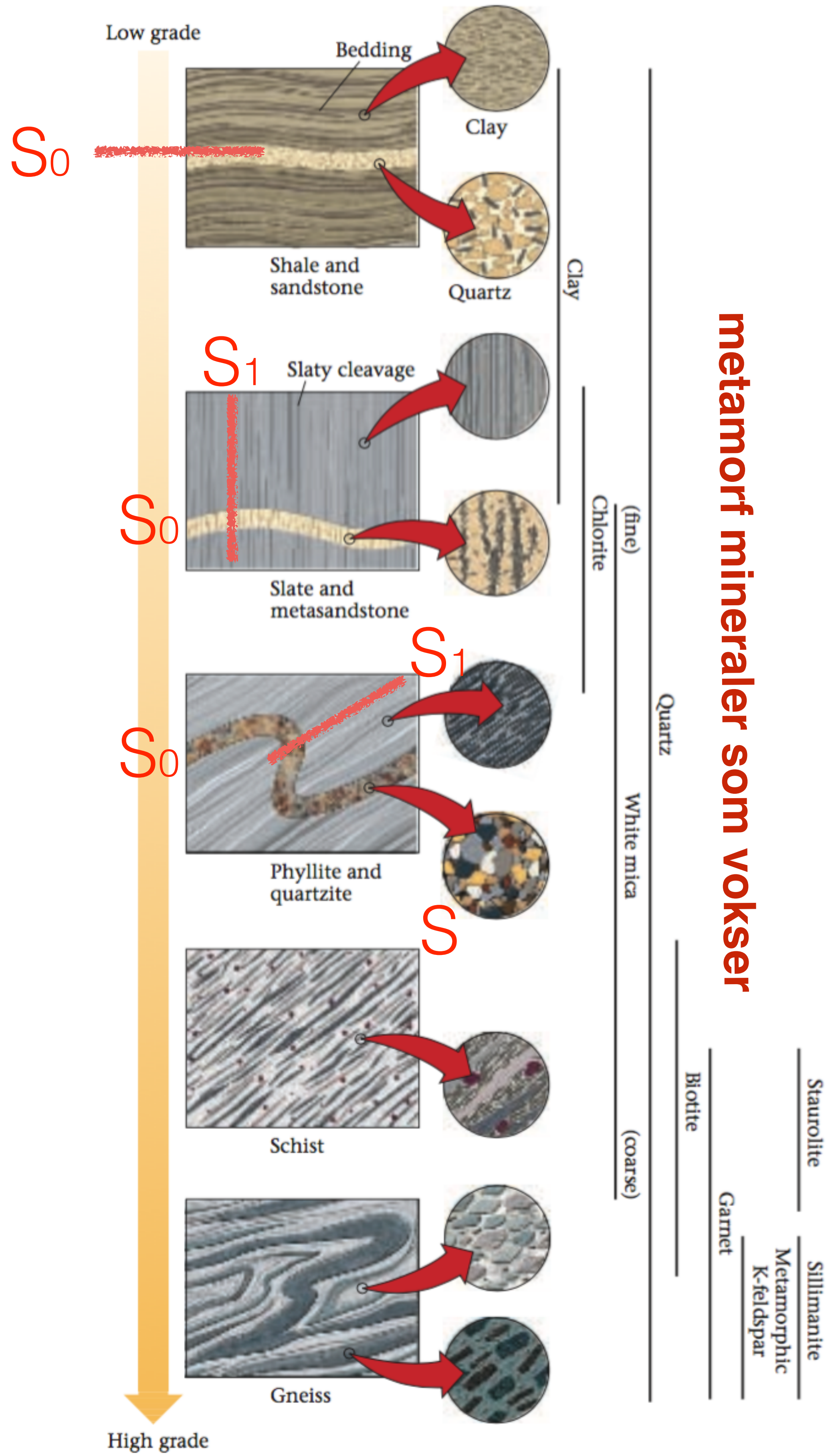
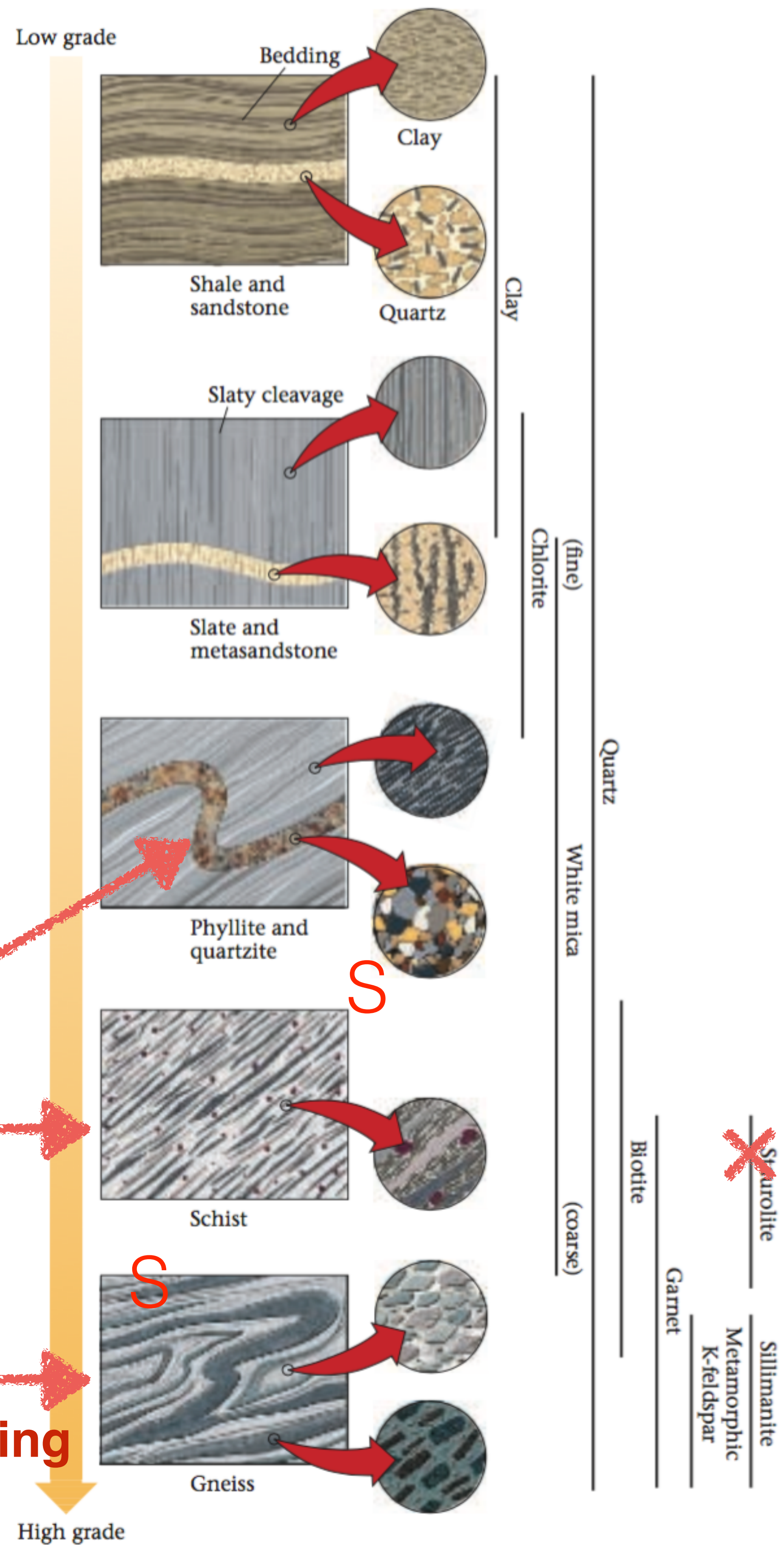


FIGURE 8.19 When shale progressively metamorphoses from low grade to high grade, it first becomes slate, then phyllite, then schist, then gneiss. In many cases, gneiss and schist can form under the same conditions. The side graph shows the stability range of various minerals.

Marshak.pdf (page 269



Opprinnelig lag kan også forsvinne under metamorfose

Ny lagning på grunn av metamorf differensiering

FIGURE 8.19 When shale progressively metamorphoses from low grade to high grade, it first becomes slate, then phyllite, then schist, then gneiss. In many cases, gneiss and schist can form under the same conditions. The side graph shows the stability range of various minerals.

Lyse lag kan oppstå på grunn av metamorf differensiering. Eller på grunn av partiell smelting.

Hvis partiell smelting, kalles bergarten Migmatitt.

Vanligvis vokser mineraler **større** med mer metamorfose

Men hvis det er mye deformasjon, mineralene “mølles ned” til finkornet ba.

bør hete “møllen-itt” :)

Mylonitt

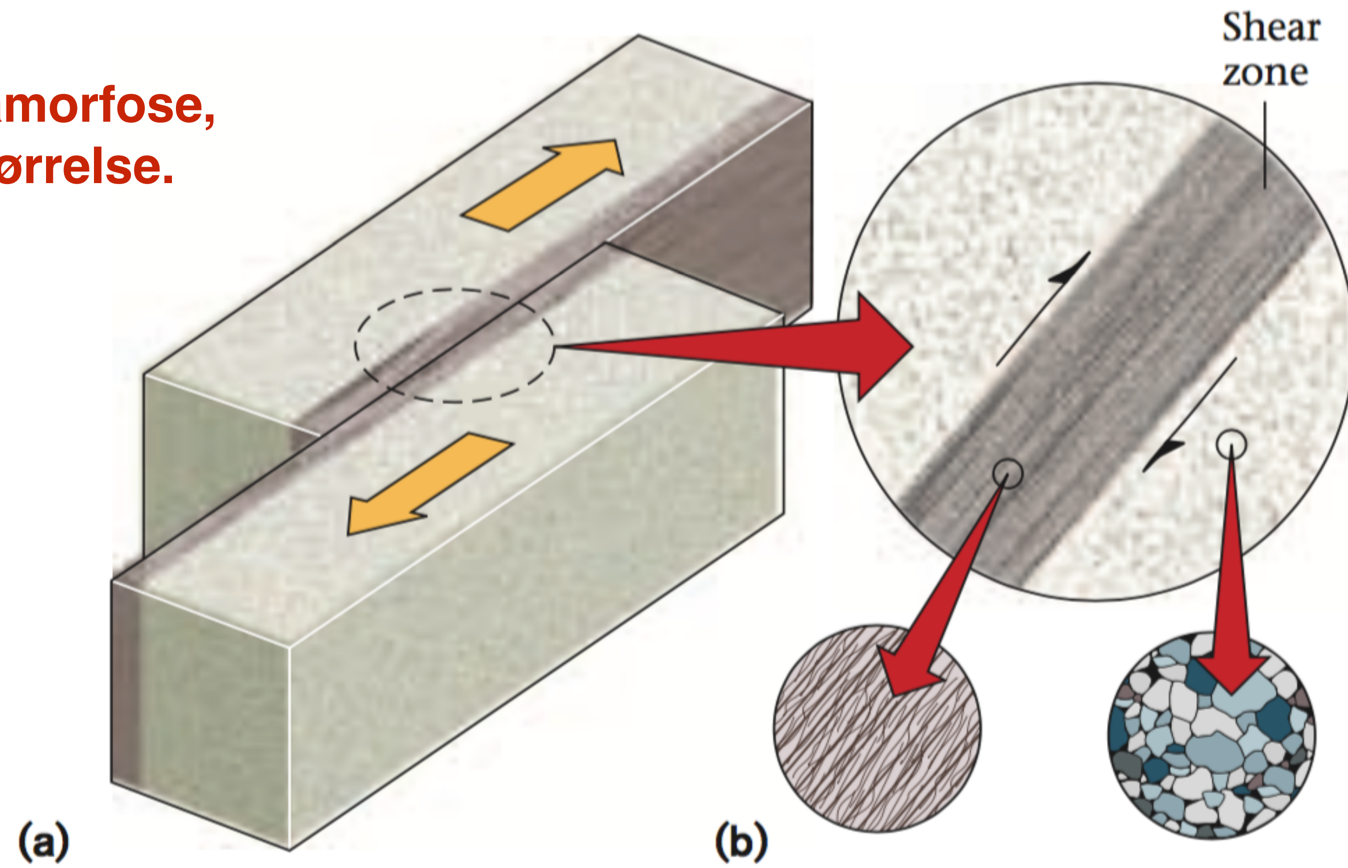
Marshak.pdf (page 276 of 957)

Mylonite in a shear zone

Marshak.pdf (page 274 of 957)

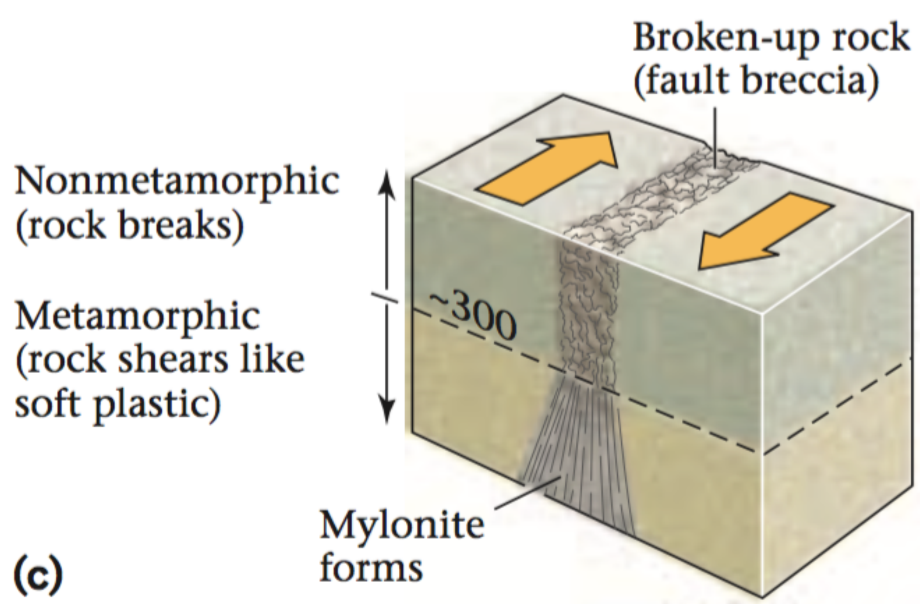
Med vanlig prograd metamorfose, blir det økning i kornstørrelse.

kornstørrelsesreduksjon



Forkastningsbreksje: —> ingen foliasjon (for lavt T, P)

Mylonitt: —> foliasjon (høy nok T, P)

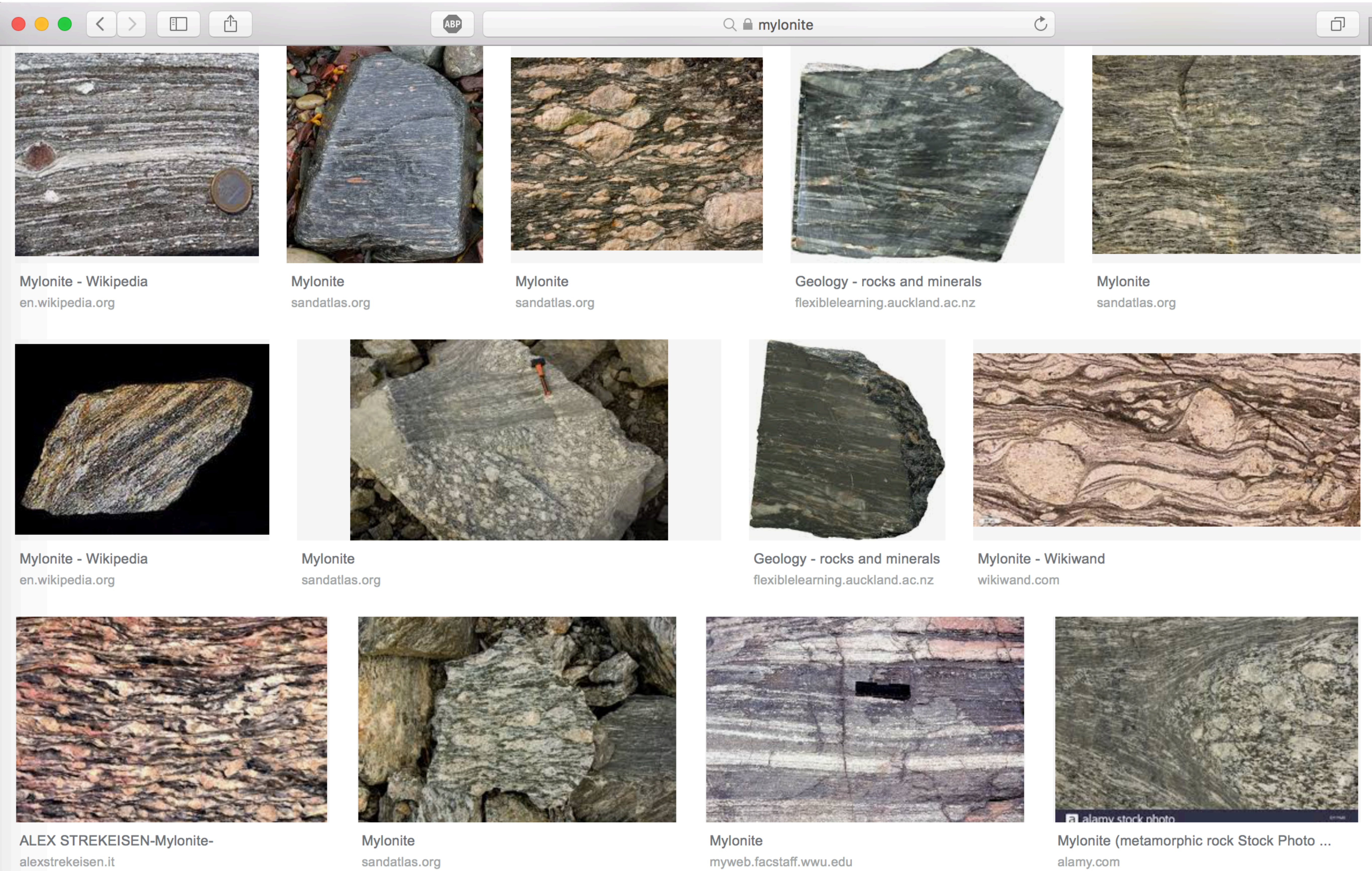


Forkastningsbreksje dannes kun grunt, mindre enn 300° temperatur. Knusing, uten dannelse av foliasjon

Mylonitt dannes ved minst 10 km dybde, over 300° temperatur

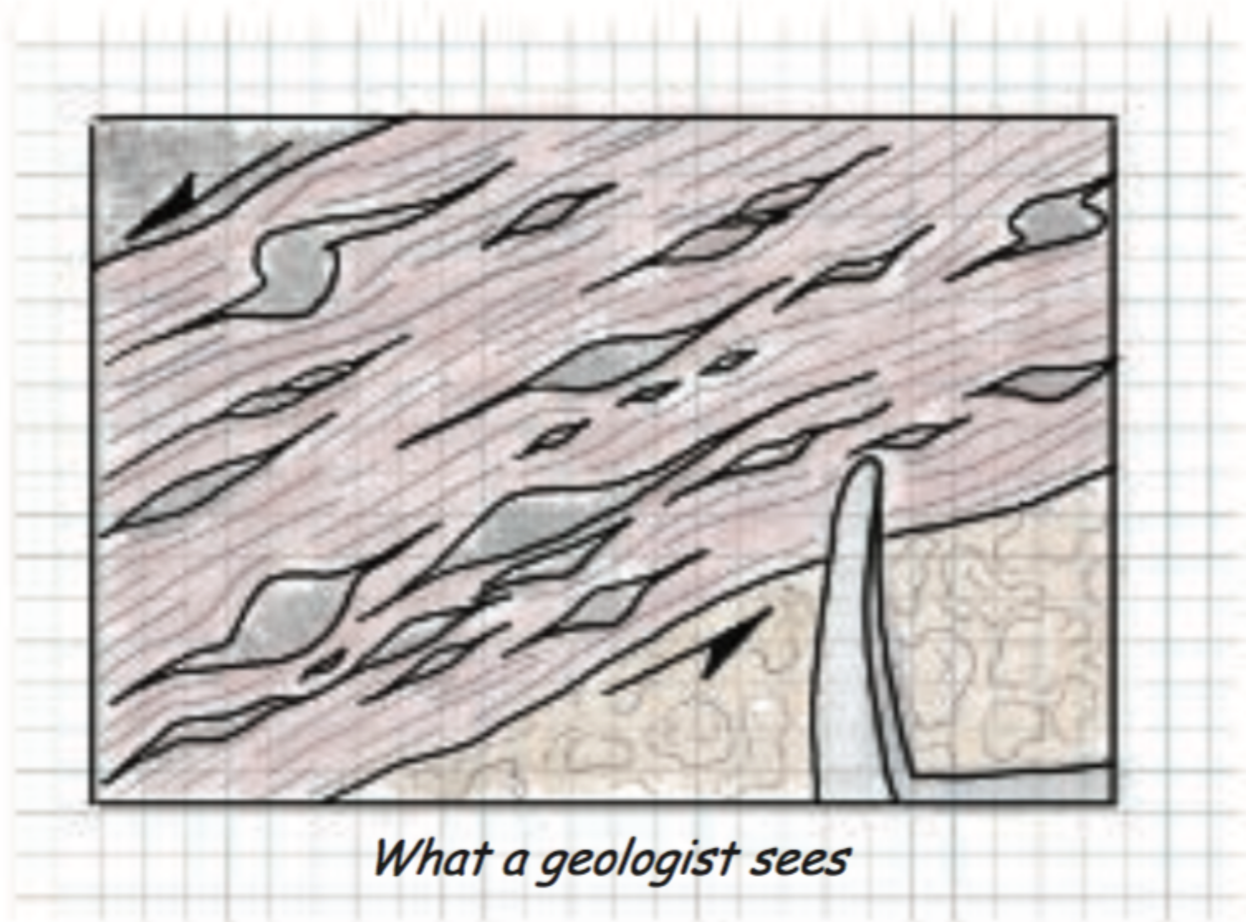
FIGURE 8.25 Dynamic metamorphism along a fault zone. **(a)** Note the band of sheared rock on either side of the slip surface. **(b)** The rock outside the shear zone has a different texture from that of the rock inside. **(c)** The block formed in (a) must have developed at a depth where metamorphic conditions exist, so that mylonite forms; otherwise, it would break up during movement.

mylonitt: feltspater motstår nedknusing, og består som porfyroklaster.



(e)

Porfyroklaster av feltspat

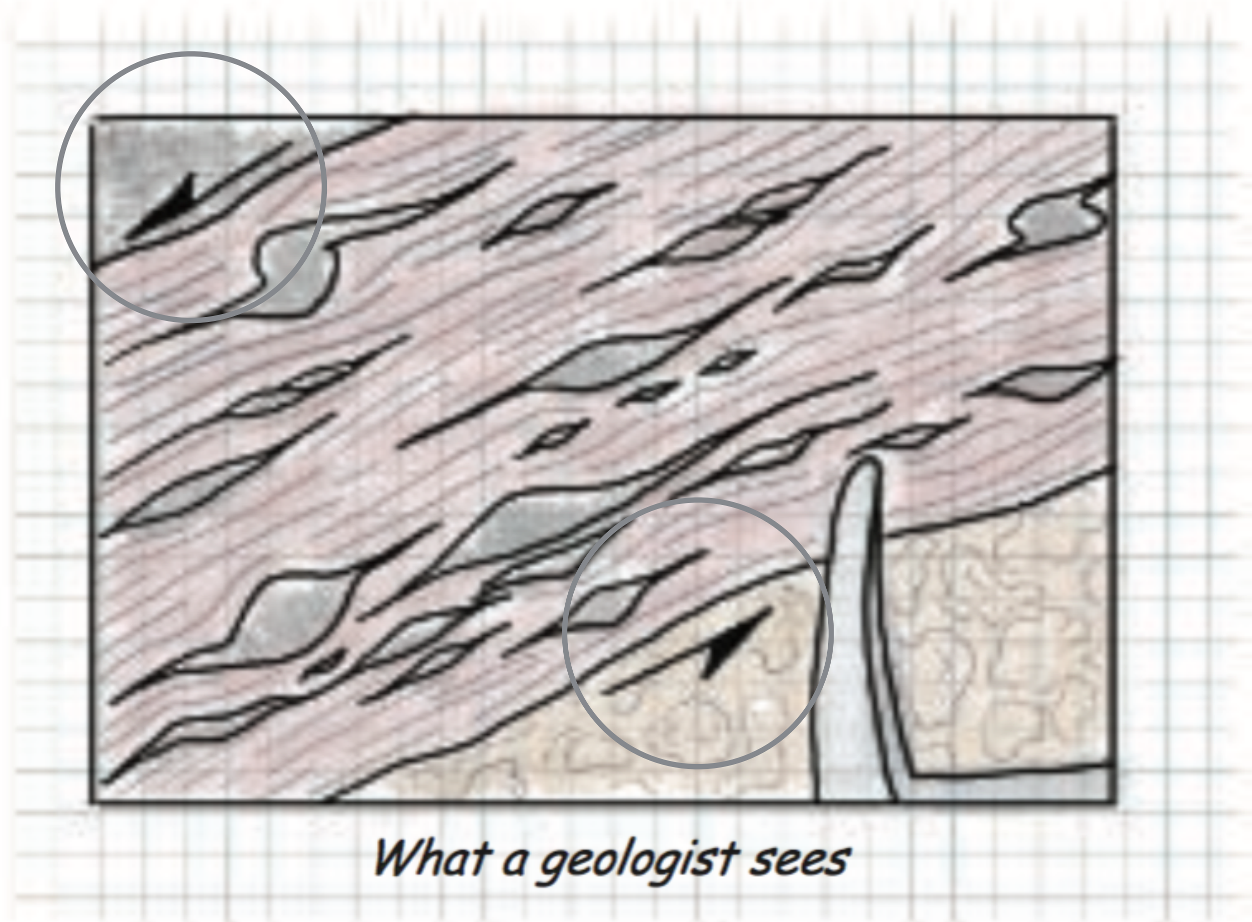


(f)

Store mineraler som knuses
heter “porfyroklaster”
f.eks. kalifeltspat “øyner” i øyegneis (ekskursjon 3)

Store mineraler som vokser
heter “porfyroblaster”
f.eks. pyritt kuber (ekskursjon 1), granater (ekskursjon 3),

(e)



(f)

Bergarten heter “augen gneiss” eller “øyegneis”

Merk skjær retning er tolket her

Schou Jensen.pdf (page 95 of 112)

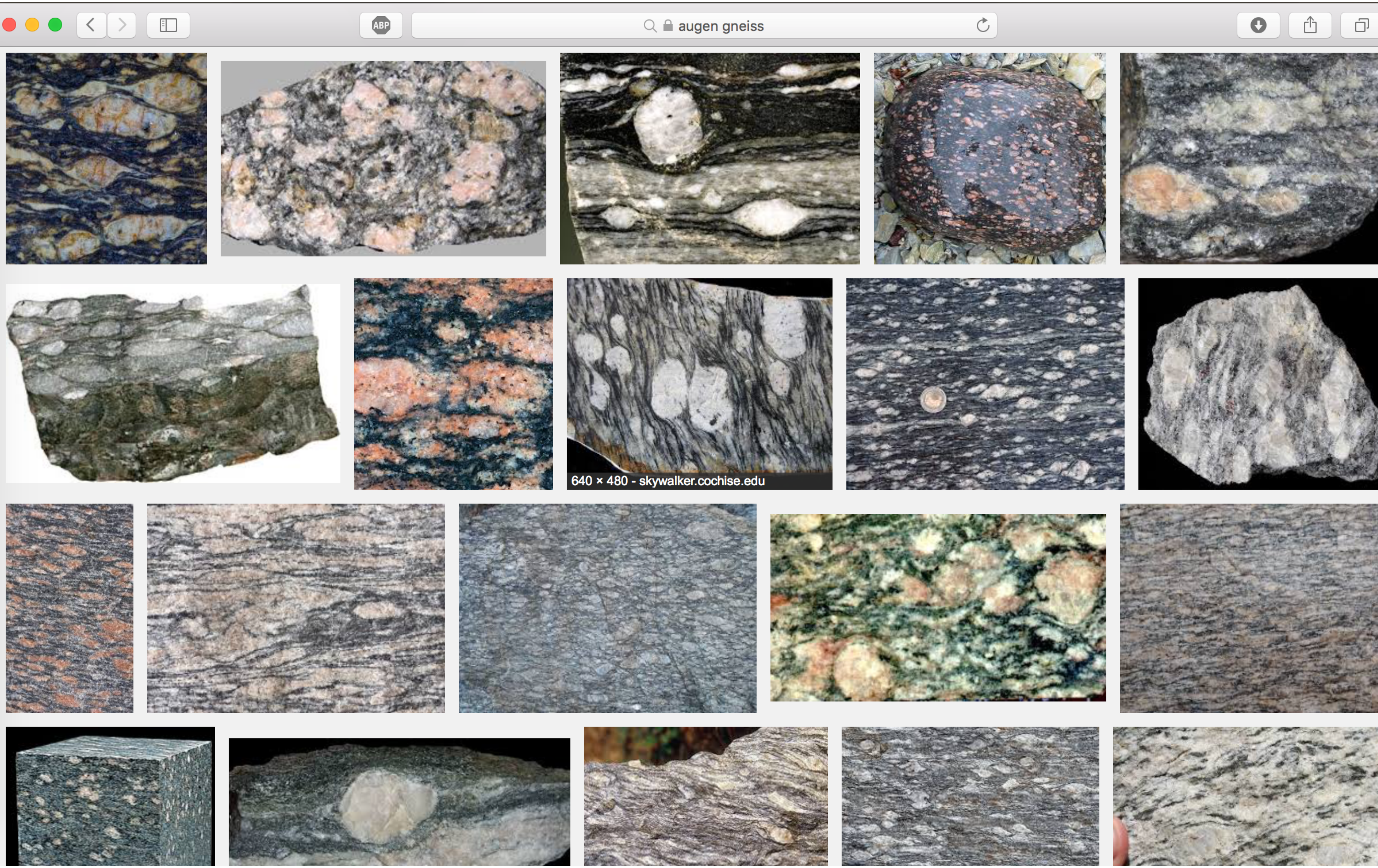
Av og til blir det dannet nye mineraler i gneisen, vanligvis kali-feltspat og granat, som store mine-ralkorn i forbindelse med metamor-fosen. De inngår i foldingen og roteres under foldingsprosessen. Samtidig skjer det ofte en viss ut-valsing, slik at mineralkornene får et øyeliknende ut-seende. En slik bergart kalles derfor øyegneis.

Disse kalifeltspat øyner er porfyro*klaster*, ikke porfyro*blaster*

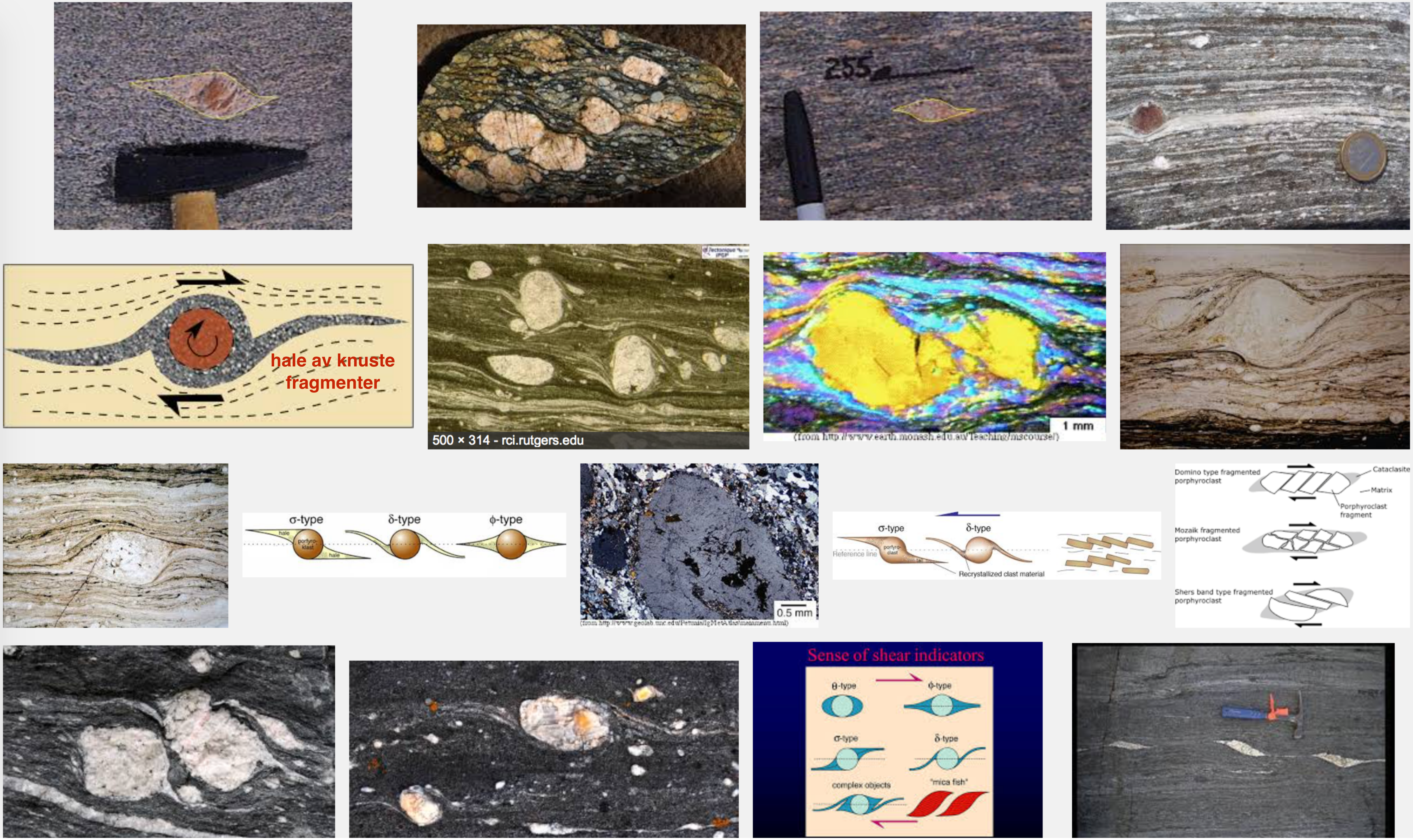
Øyegneis

Schou Jensen gir en gammel, feil tolkning her. Øyegneiser har magmatisk kalifeltspatkrystaller som ble delvis knust ned under metamorfosen. Ingen metamorf vekst av kalifeltspat her

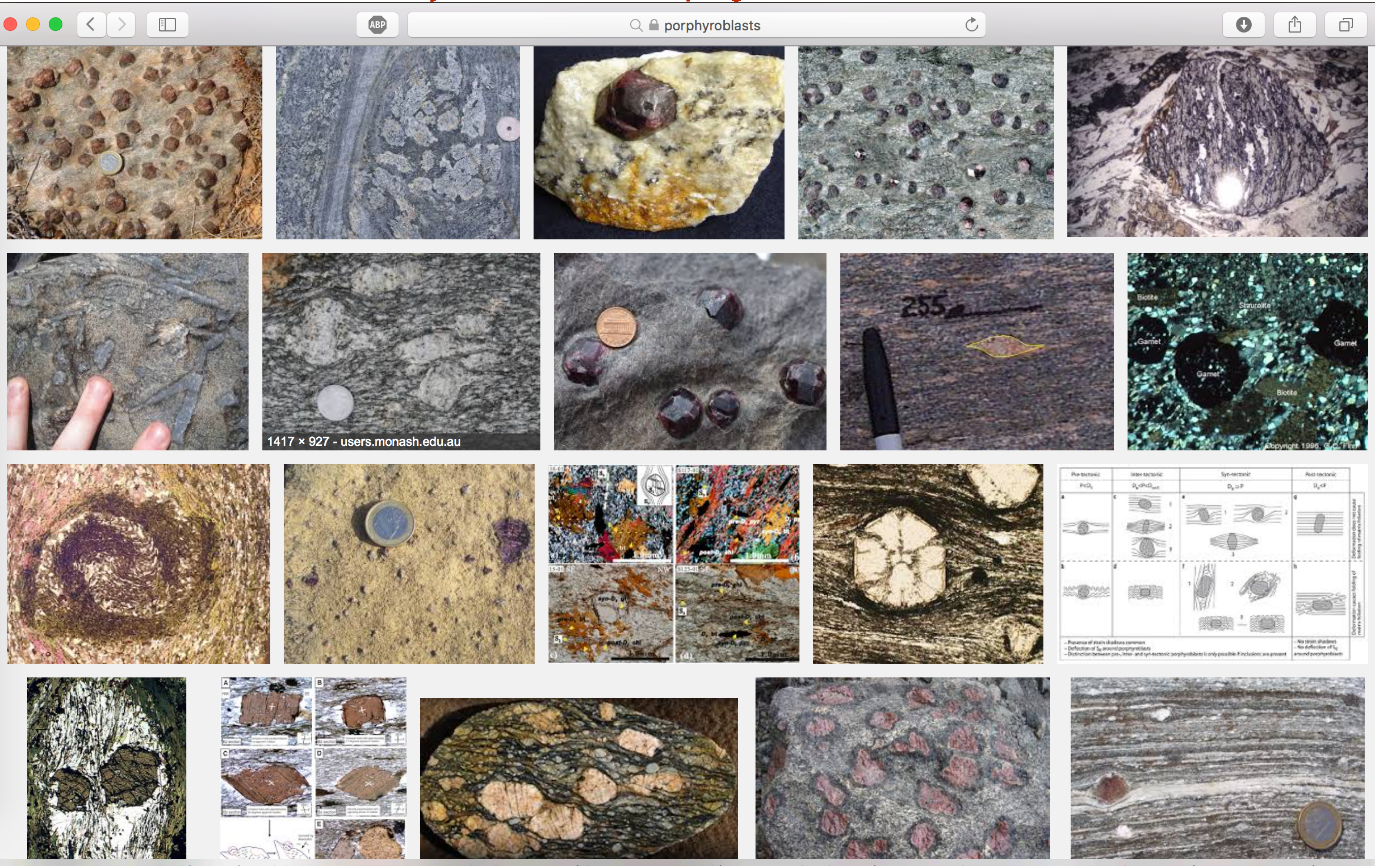
øyegneis: krystaller (porfyroklaster) av kalifeltspat

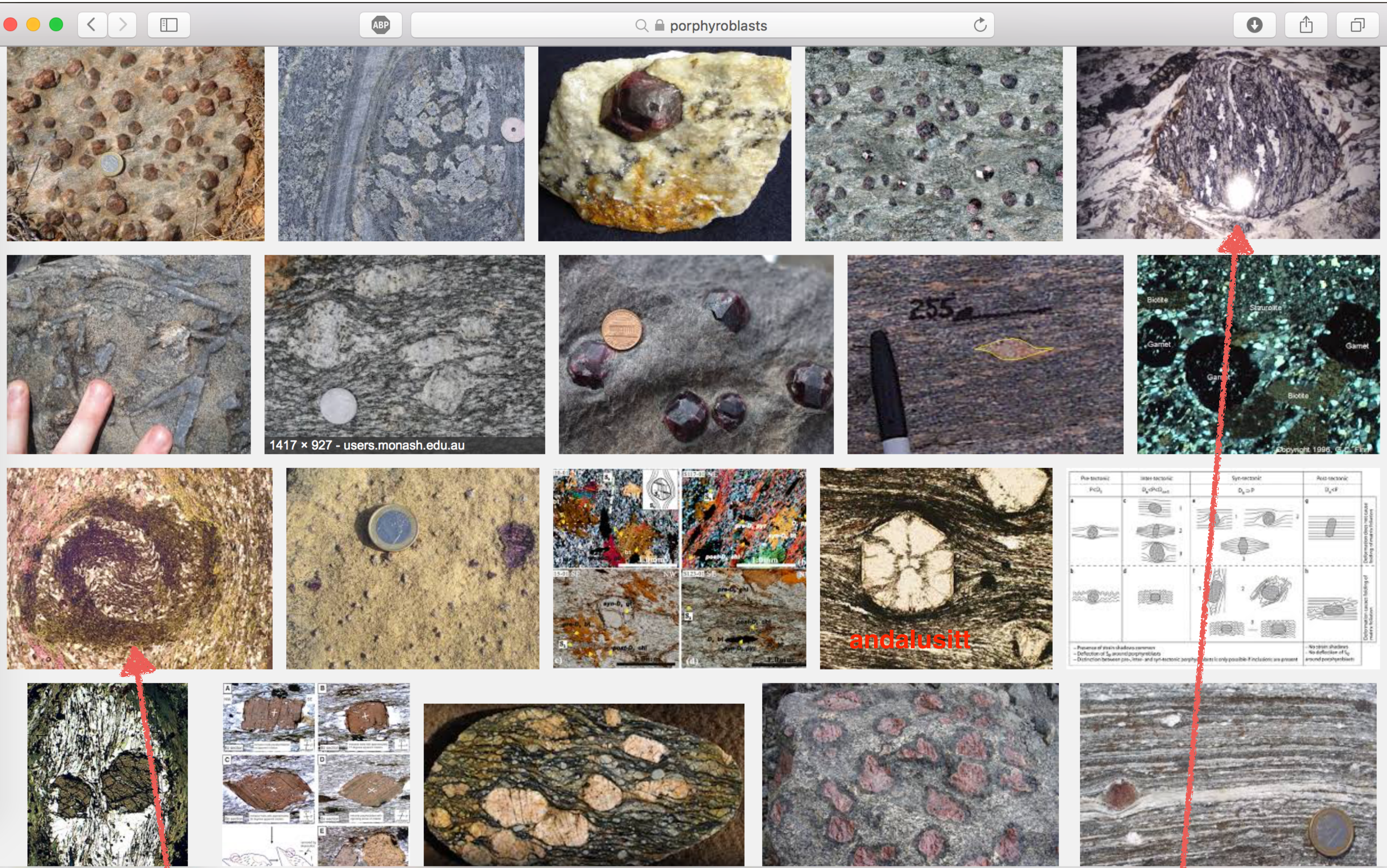


Porfyroklaster. disse knuses mindre.



Porfyroblaster. for eksempel granat. disse vokser større





ruller med klokka

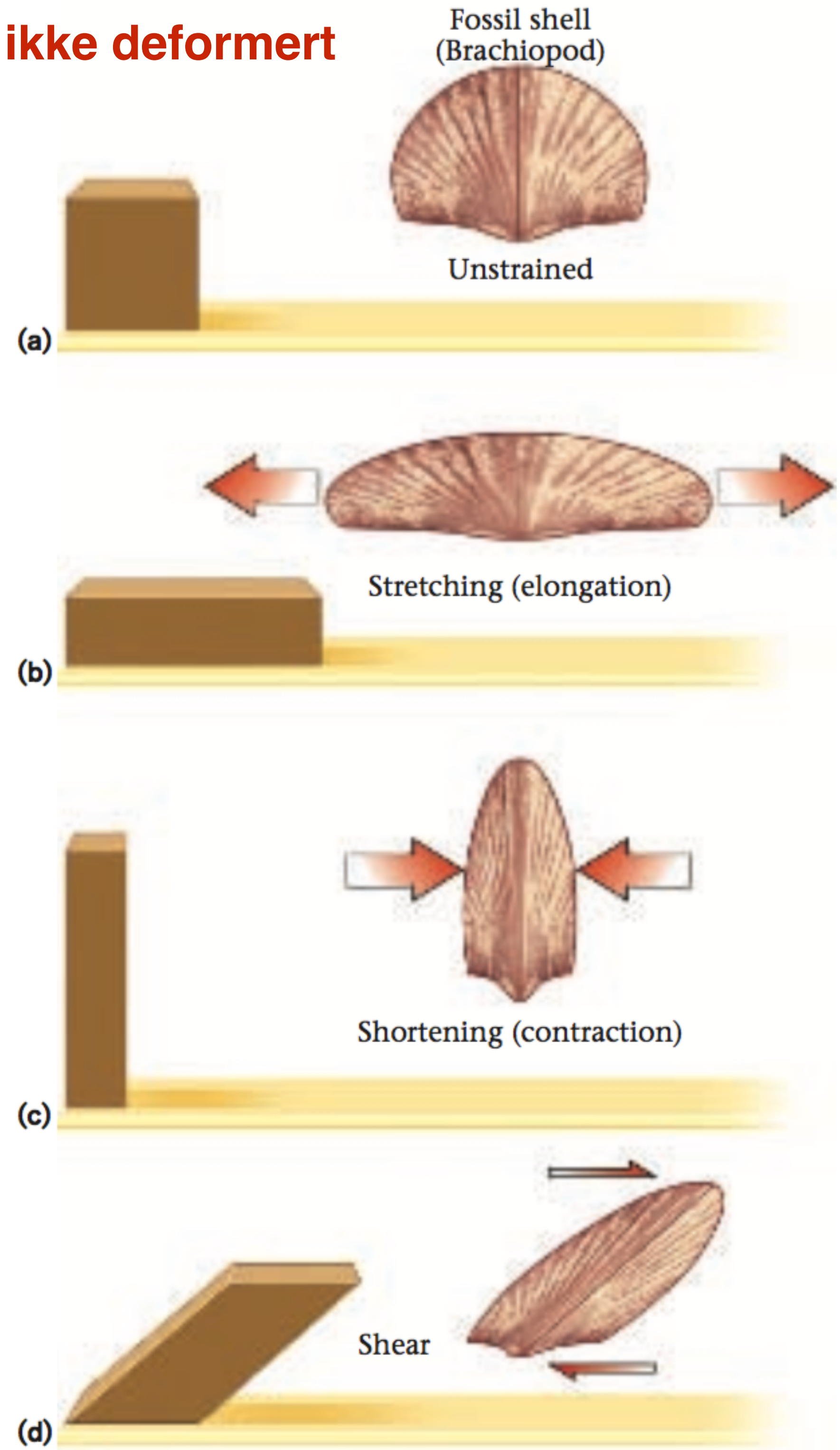
“snøball granater” sees i tynnslip
inneslutninger av kvarts og biotitt
viser tidlige foliasjon som er fanget i granaten mens den ruller og vokser

ruller mot klokka

ikke deformert

FIGURE 11.5 **(a)** Undeformed, flat-lying beds of sediment in Badlands National Monument, South Dakota. **(b)** Tilted beds of strata in Arizona. The tilting is a manifestation of deformation. **(c)** Folded layers of quartzite in Vermont. The folding is also a manifestation of deformation. Note the coin for scale.

ikke deformert



"strekning"

"forkortning"

"skjær"

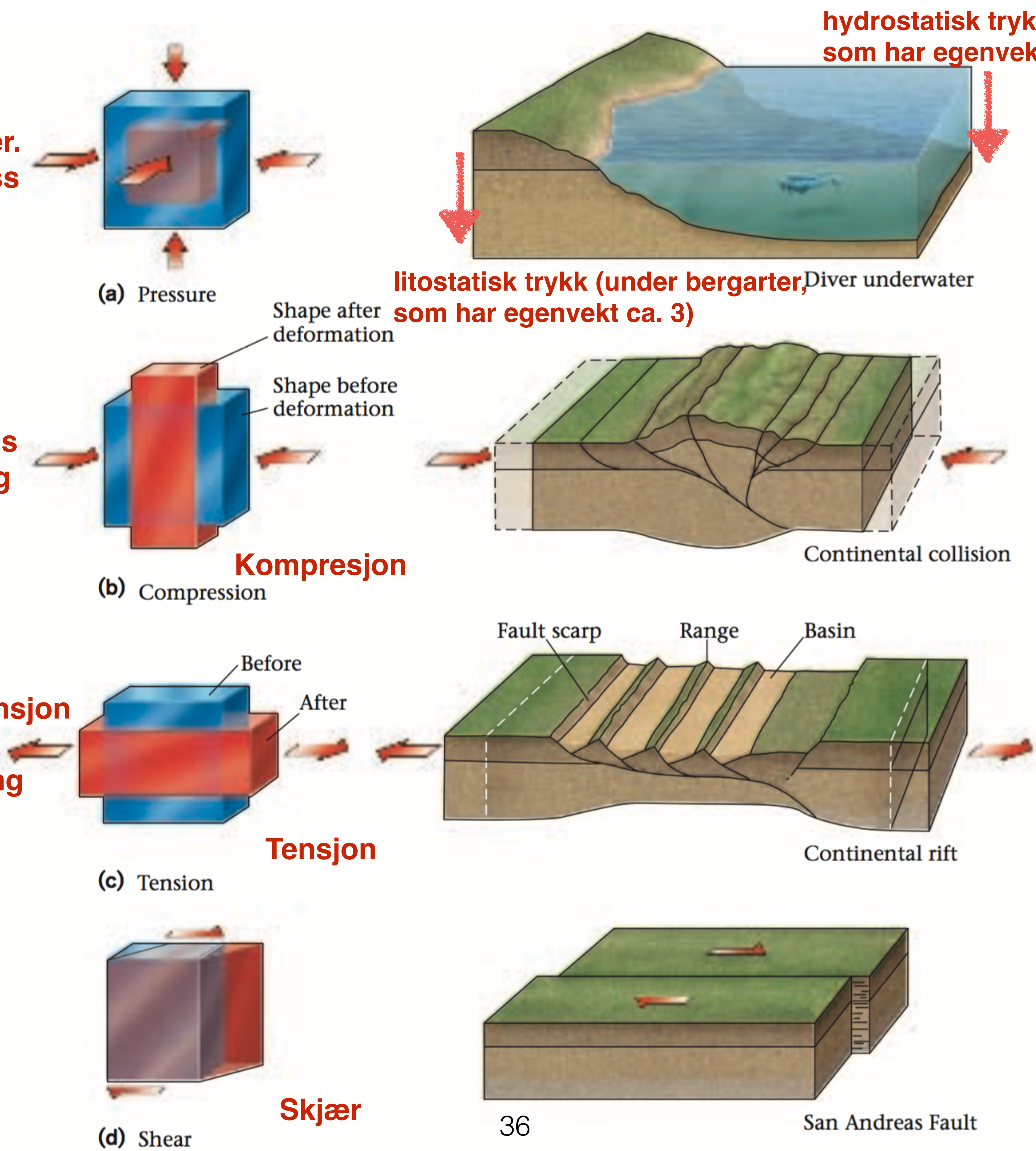
FIGURE 11.7 Different kinds of strain. **(a)** An unstrained cube and an unstrained fossil shell (brachiopod). **(b)** Horizontal stretching changes the cube into a brick whose long dimension parallels the direction of stretching, and it makes the brachiopod longer. **(c)** Horizontal shortening changes the cube into a brick whose long dimension lies perpendicular to the shortening direction, and it makes the brachiopod taller. **(d)** Shear strain tilts the cube over and transforms it into a parallelogram, and it changes the angular relationships in the brachiopod.

trykk i alle retninger.
ingen dirigert stress

kompresjons stress
fører til forkortning

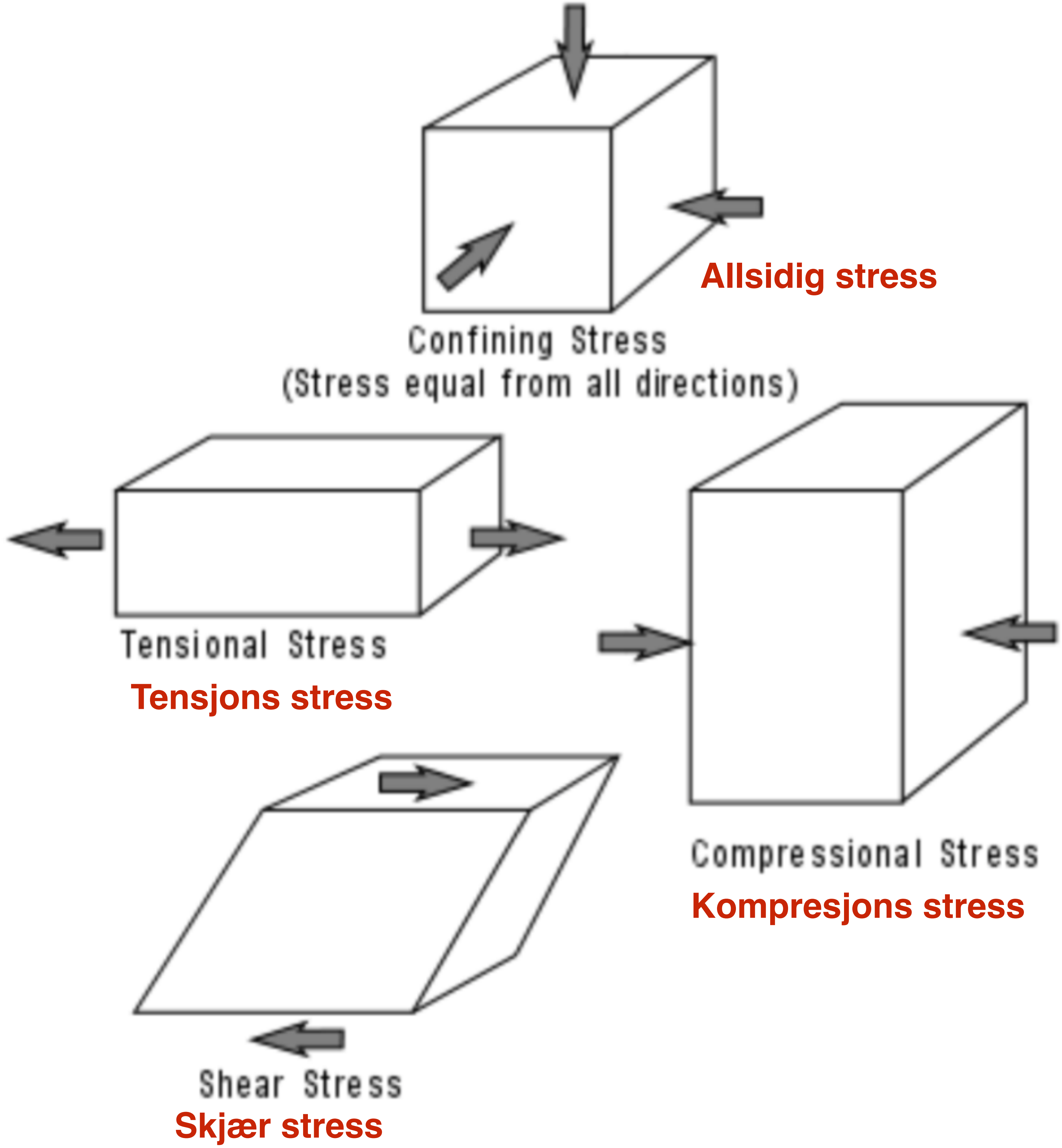
tensjon eller ekstensjon
stress
fører til strekning

skjær stress
fører til skjær



If stress is not equal from all directions then we say that the stress is a differential stress. Three kinds of differential stress occur.

1. ***Tensional stress (or extensional stress)***, which stretches rock;
2. ***Compressional stress***, which squeezes rock; and
3. ***Shear stress***, which result in slippage and translation.



When rocks deform they are said to ***strain***. A strain is a change in size, shape, or volume of a
deformere deformasjon

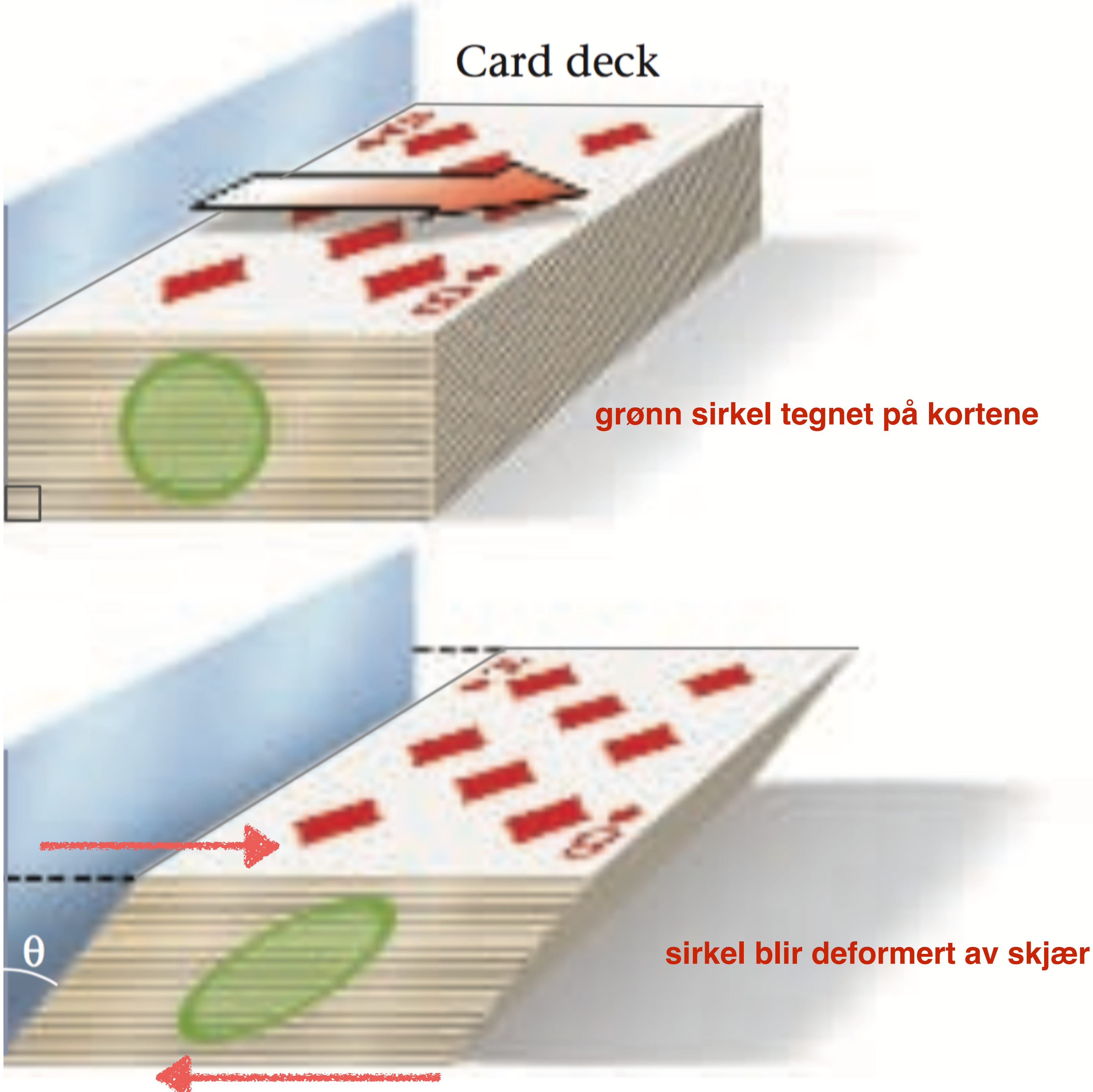
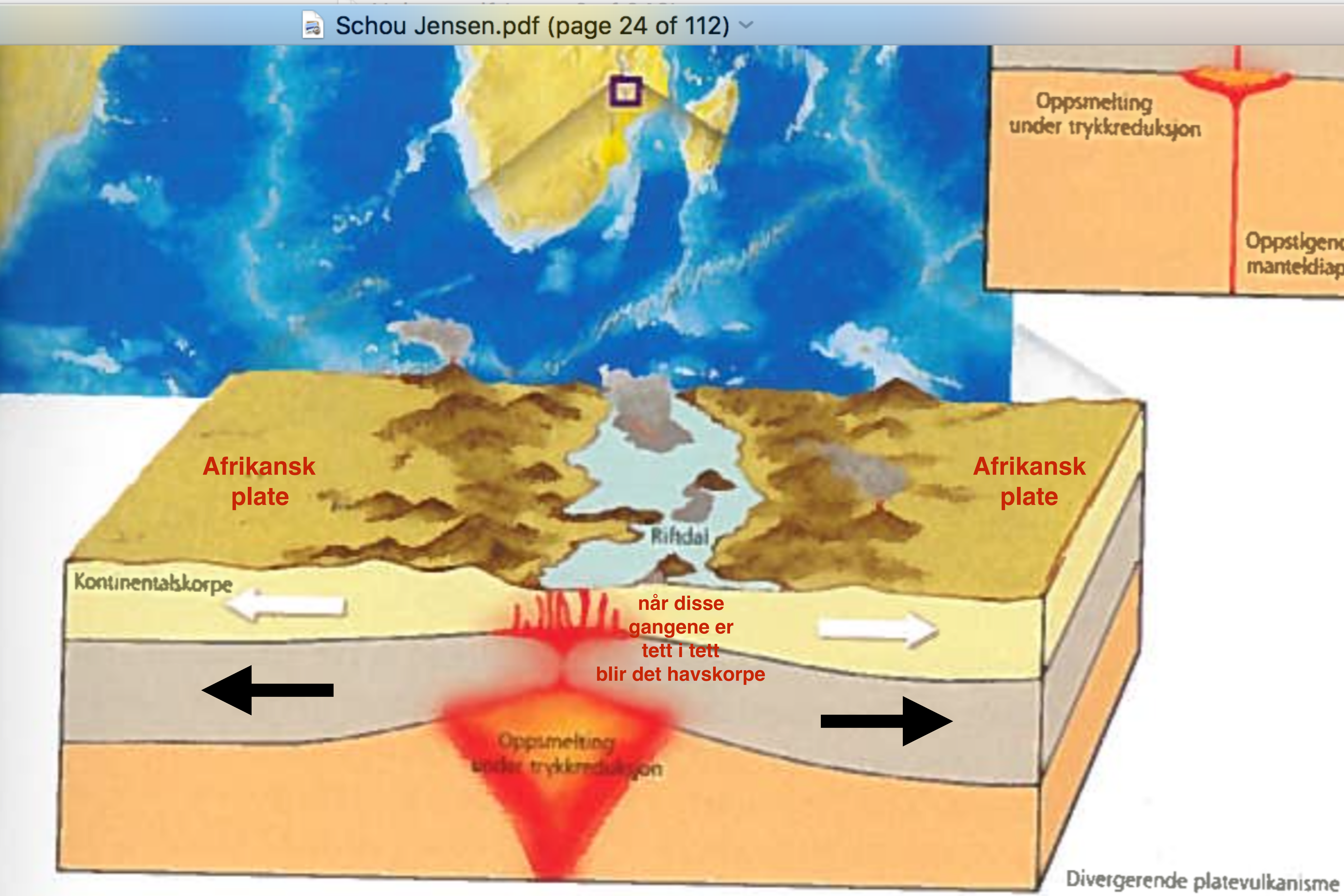
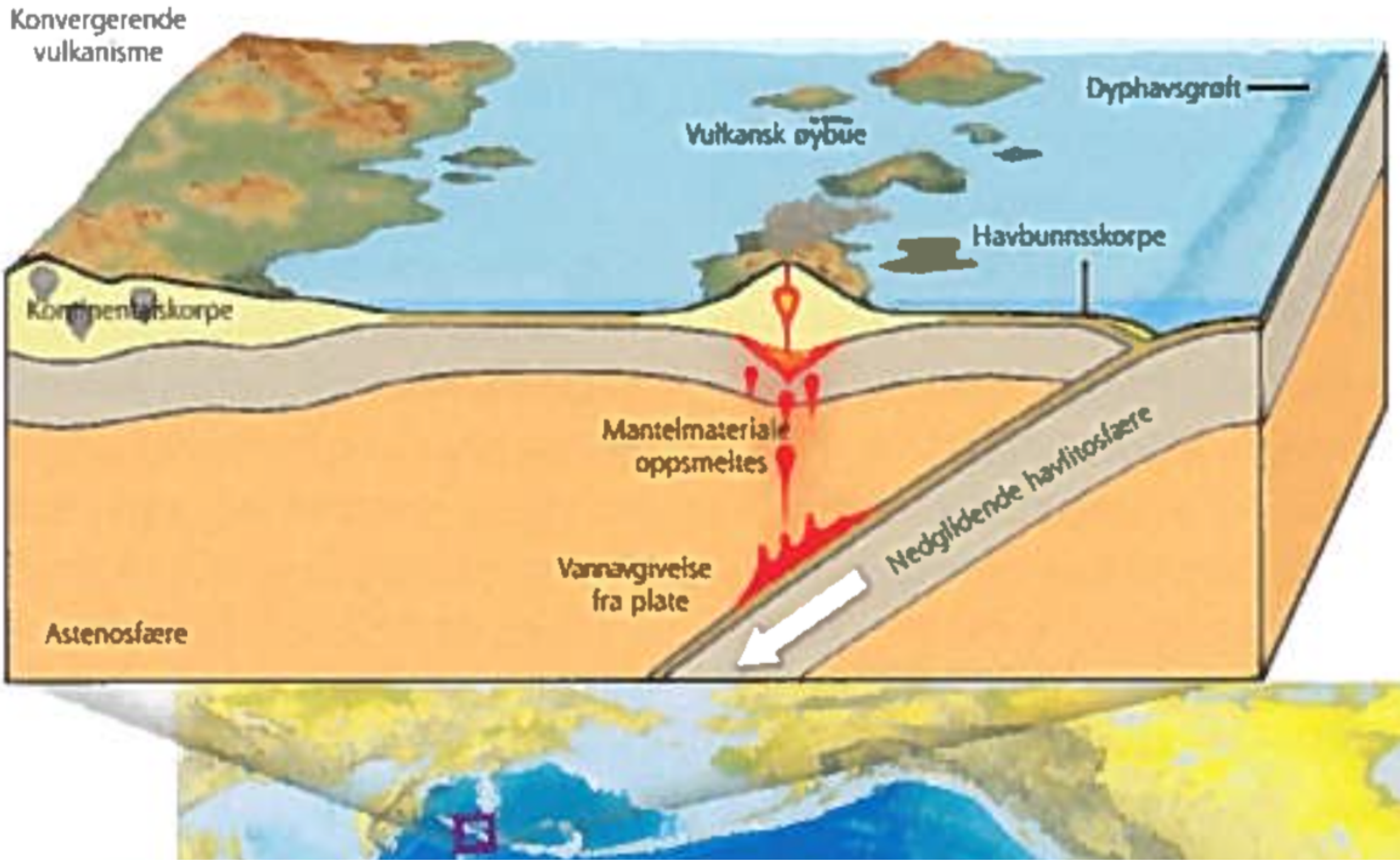


FIGURE 11.8 You can simulate shear strain by moving a deck of cards

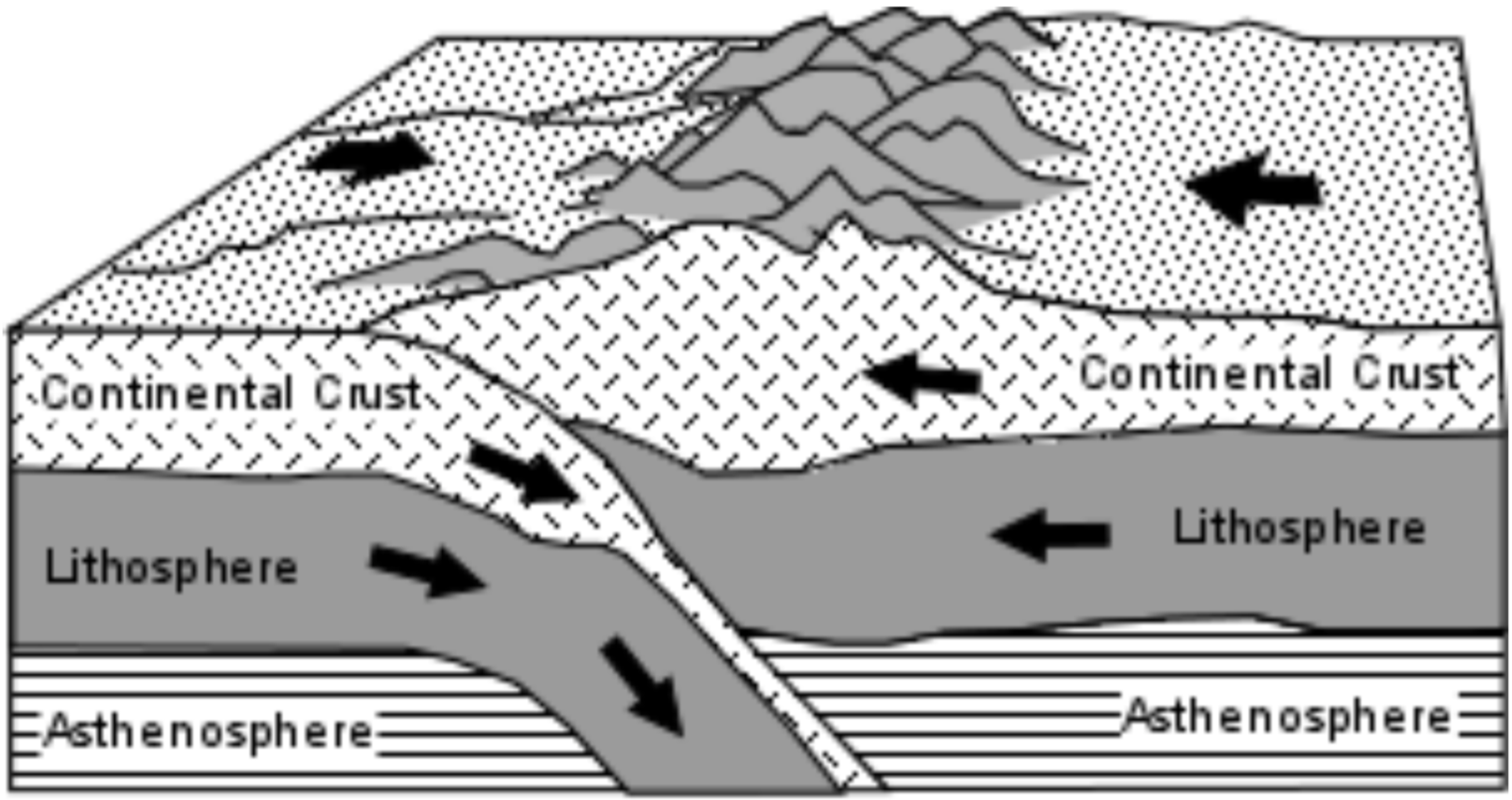


Oppsmelting pga. trykkreduksjon (dekompresjon)

Schou Jensen.pdf (page 24 of 112)



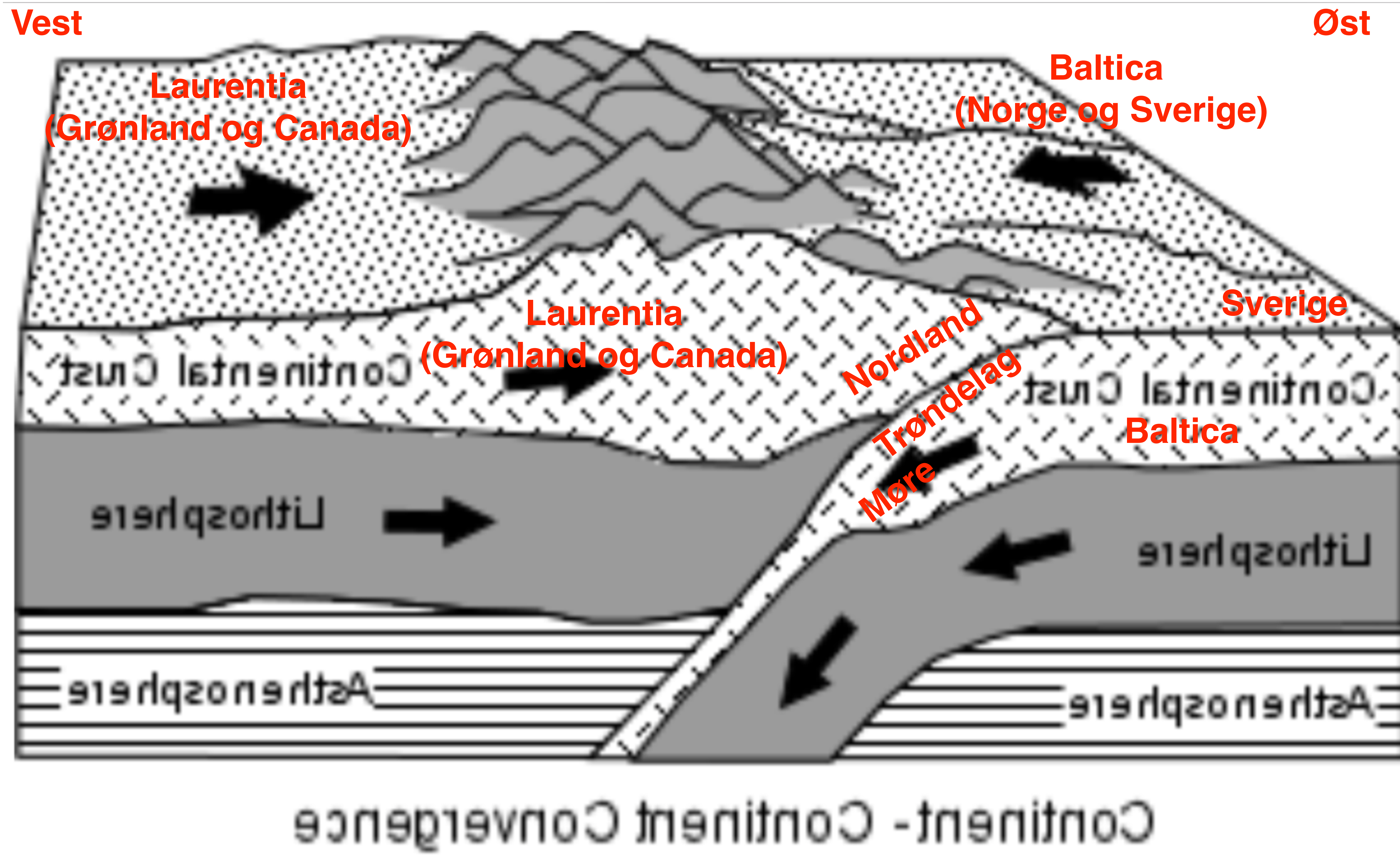
Konvergerende plategrenser

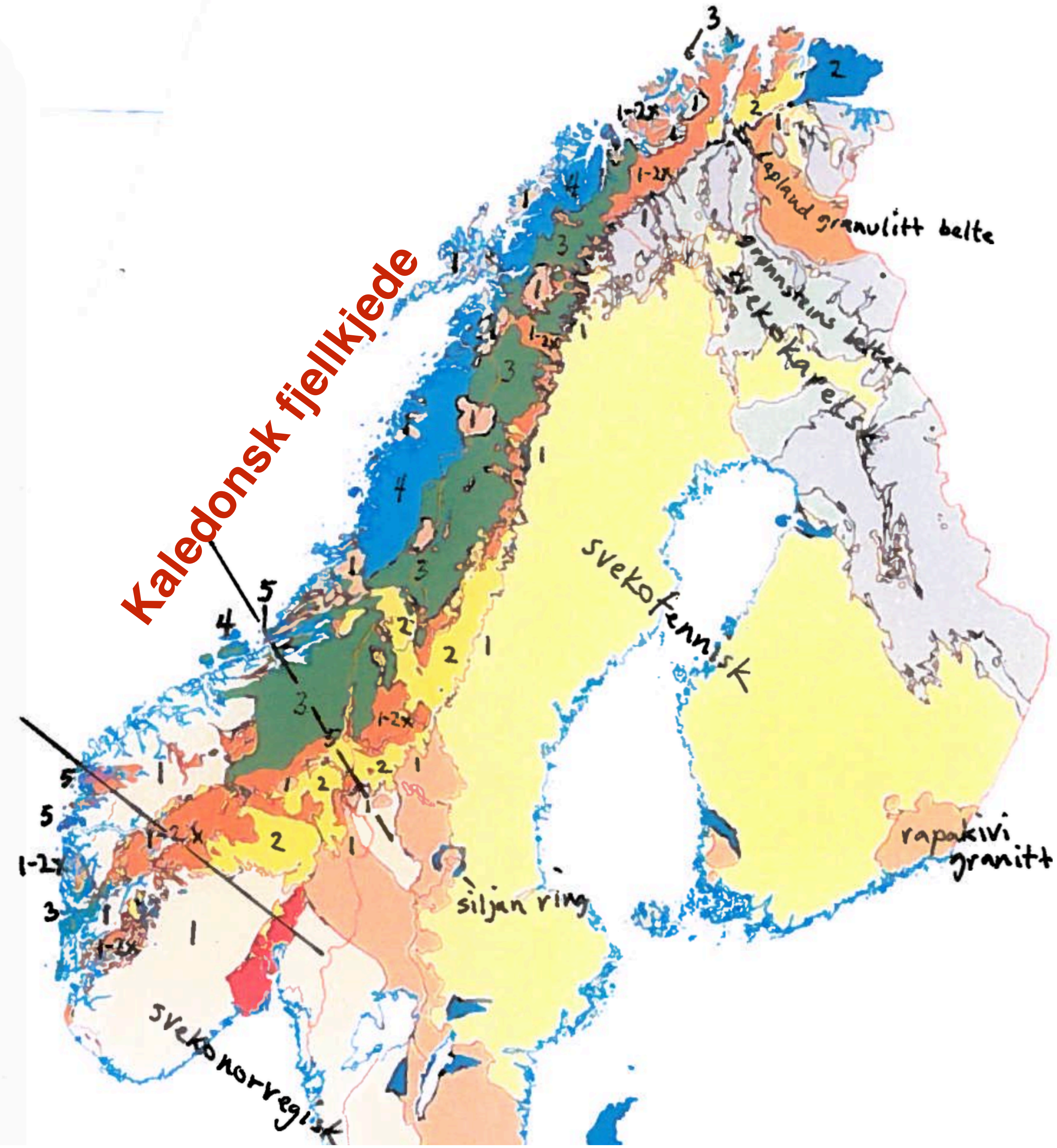


Continent- Continent Convergence

subduksjon blokkeres når kontinent treffer annen kontinent (kontinent-kontinent kollisjon)

I en tidligere kollisjonen gikk “Baltica” under “Laurentia” (“Kaledonsk” fjellkjededannelse, 400 millioner år siden)





Tegnforklaring
Legend

- Osloriften; perm - karbon / *Oslo Rift (Permian - Carboniferous)*
- Sedimenter utenfor den kaledonske fjellkjeden (neoproterozoikum-fanerozoikum) / *Sediments outside the Caledonian Orogen (Neoproterozoic-Phanerozoic)*

Bergarter i den kaledonske fjellkjeden
Rocks within the Caledonian Orogen

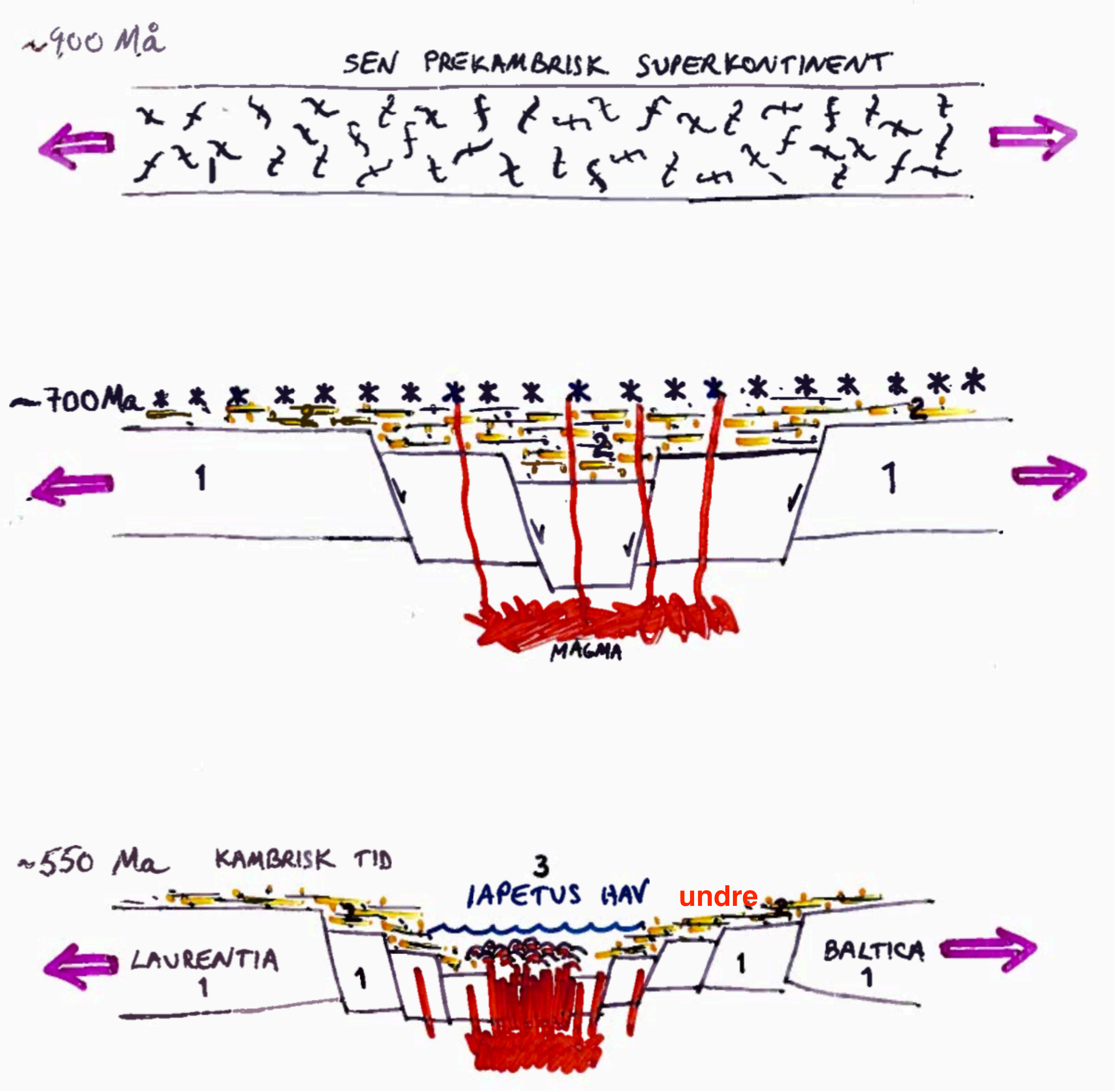
- 5 — Sedimentbasenger i fjellkjeden (sensilur - devon) / *Intermontane basin deposits (Late Silurian - Devonian)*
- øverste — 4 — Øverste dekkeserie (neoproterozoikum - ordovicium) / *Uppermost Allochthon (Neoproterozoic - Ordovician)*
- øvre — 3 — Øvre dekkeserie (neoproterozoikum - silur) / *Upper Allochthon (Neoproterozoic - Silurian)*
- midtre — 1-2x — Midtre dekkeserie (mesoproterozikum - cambrium) / *Middle Allochthon (Mesoproterozic - Cambrian)*
- undre — 2 — Undre dekkeserie (mesoproterozoikum - paleozoikum) / *Lower Allochthon (Mesoproterozoic - Palaeozoic)*

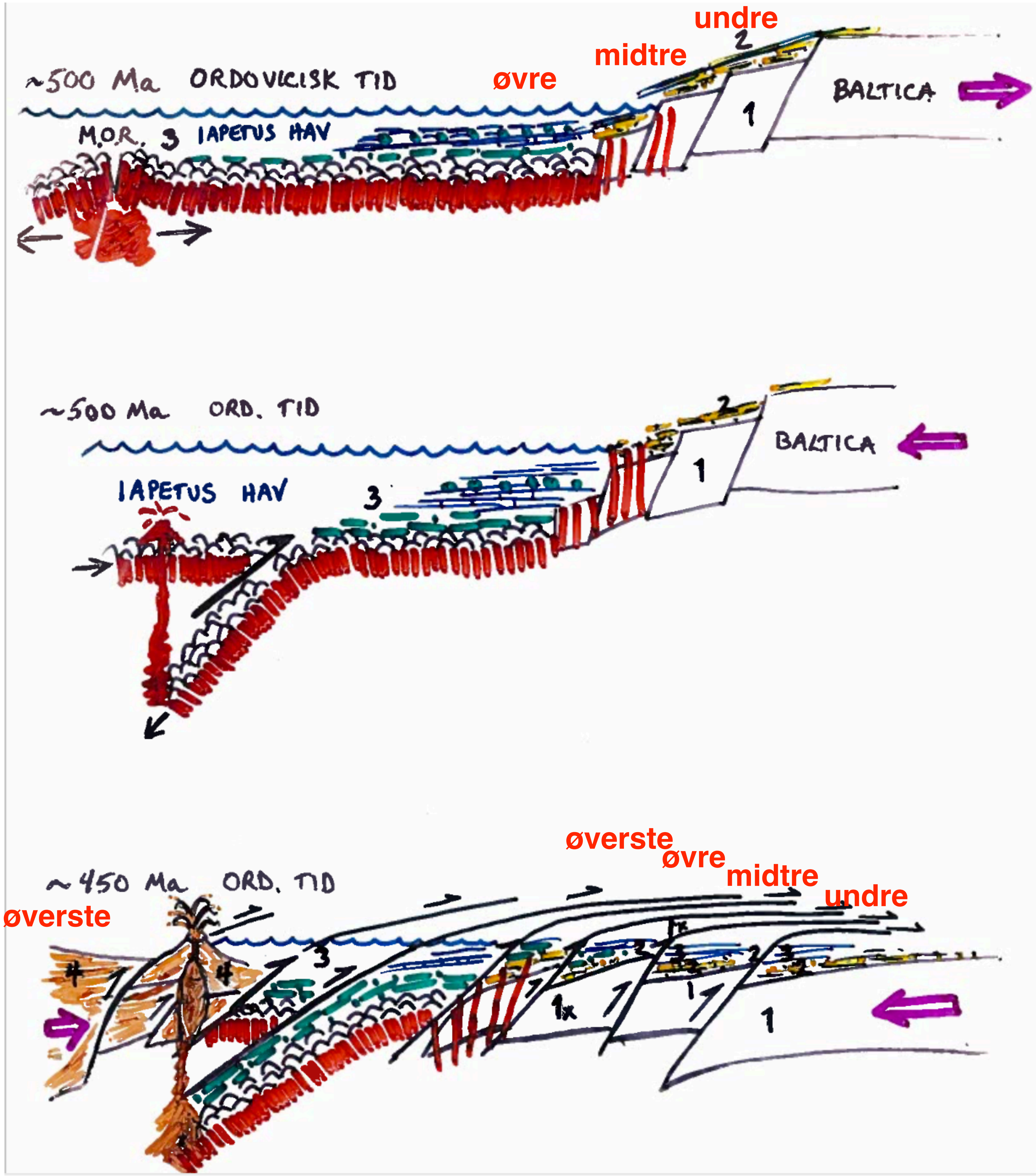
Proterozoikum
Proterozoic

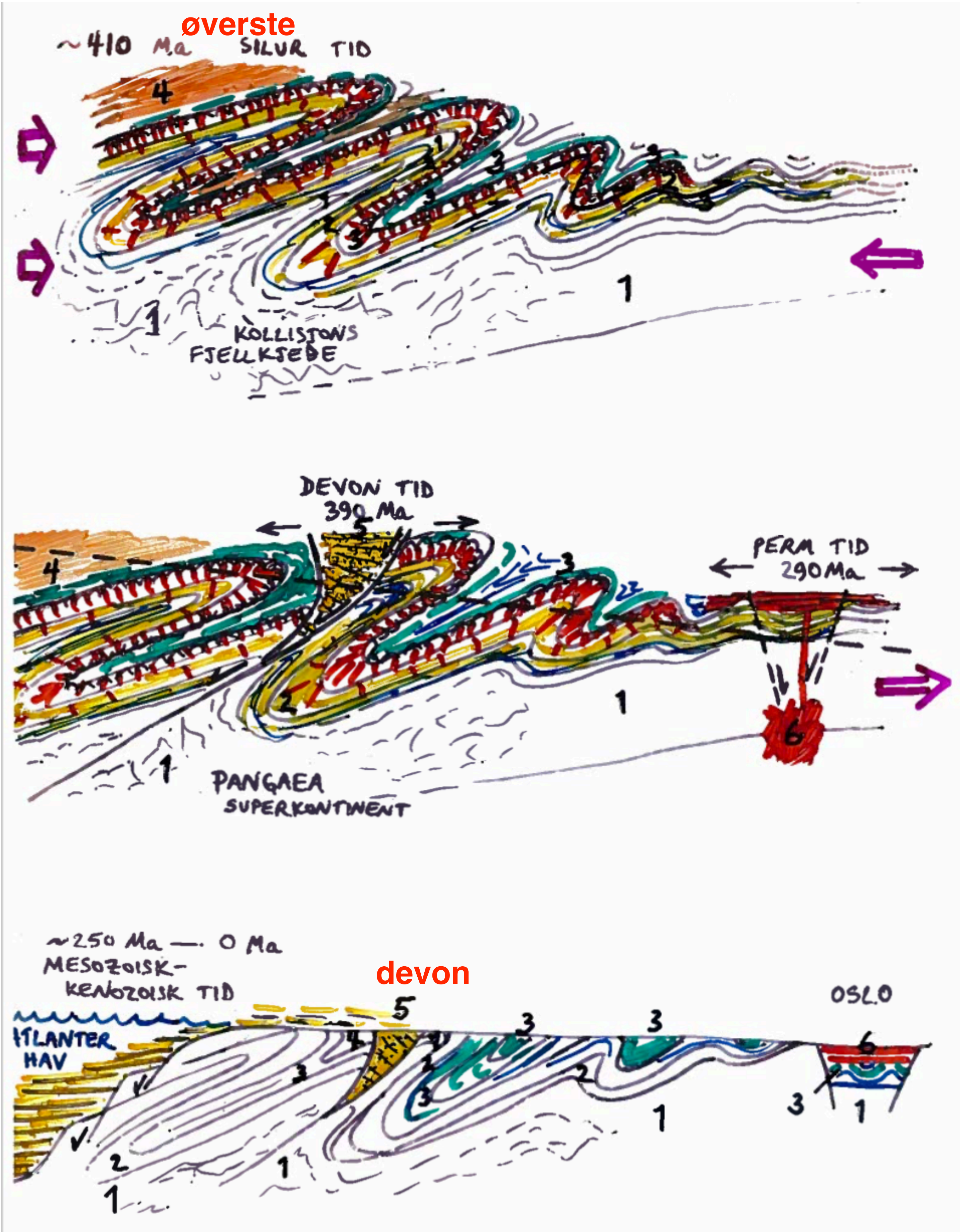
- 1 — Dyp- og overflatebergarter (1700-900 mill. år) - gotisk og svekonorvegisk / *Igneous and supracrustal rocks (1 700-900 Ma) - Gothian and Sveconorwegian*
- 1 — Det transskandinaviske intrusivbeltet og rapakivigranitt (1 800-1 650 mill. år) / *Transscandinavian Igneous Belt and rapakivi granite (1 800-1 650 Ma)*
- 1 — Dyp- og overflatebergarter (1960-1750 mill. år) - hovedsaklig svekofennisk / *Igneous and supracrustal rocks (1 960-1 750 Ma) - mainly Svecofennian*
- 1 — Dyp- og overflatebergarter (2300-1 900 mill. år) - Lapplandgranulittbeltet / *Igneous and supracrustal rocks (2300-1 900 Ma) - Lapland Granulite Belt*
- 1 — Overflatebergarter og lagdelte gabbroer (2500-1 950 mill. år) - svekokarelsk / *Supracrustal rocks and layered gabbros (2500-1 950 Ma) - Svecokarelian*

Arkeikum
Archaean

- 1 — Dyp og overflatebergarter (3200-2500 mill. år) / *Igneous and supracrustal rocks (3200-2500 Ma)*


~900 Må
SEN PREKAMBRISK SUPERKONTINENT
~700Ma
2
1
1
MAGMA
~550 Ma KAMBRISK TID
3
IAPETUS HAV
undre
2
LAURENTIA
1
1
1
BALTICA
1


~500 Ma ORDOVICISK TID
undre
2
midtre
øvre
BALTICA
1
M.O.R. 3 IAPETUS HAV
~500 Ma ORD. TID
2
BALTICA
1
IAPETUS HAV
3
~450 Ma ORD. TID
øverste
øvre
midtre
undre
øverste
4
4
3
1x
1x
1
1


~410 Ma
øverste
SILUR TID
KOLLISJONS
FJELLKJEDE
DEVON TID
390 Ma
PERM TID
290 Ma
PANGAEA
SUPERKONTINENT
~250 Ma — 0 Ma
MESOZOISK-
KENOZOISK TID
devon
TLANTER
HAV
OSLO