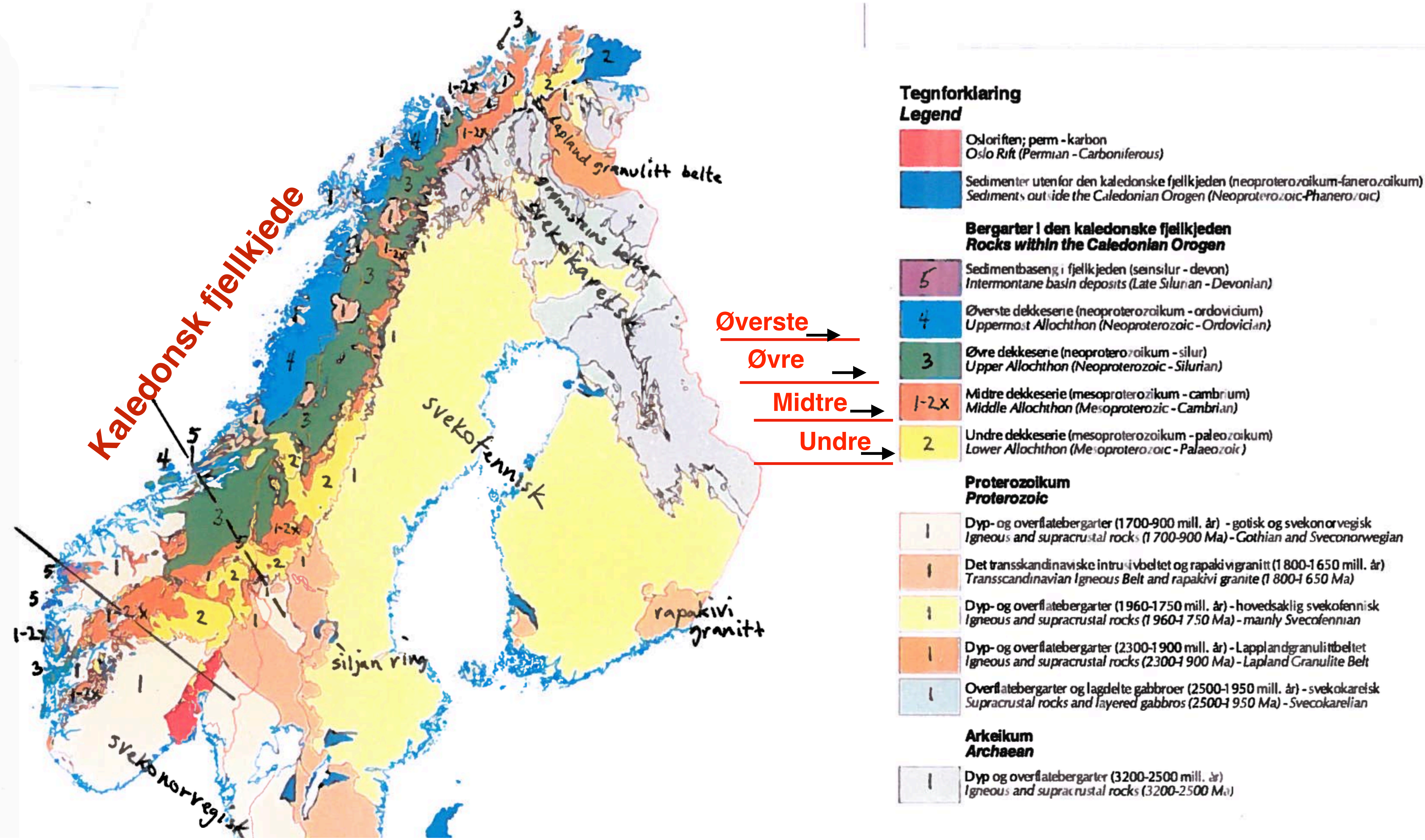
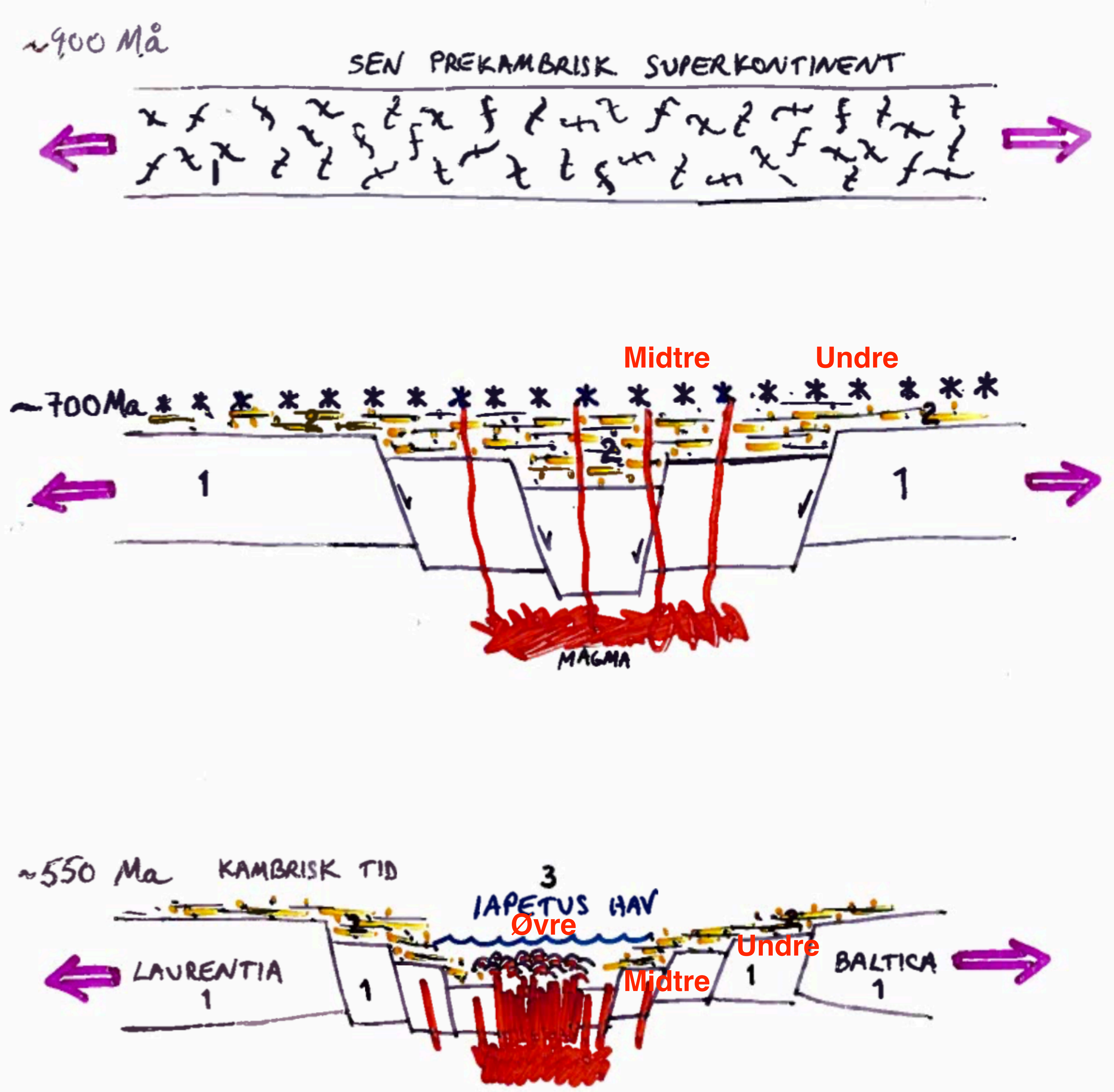
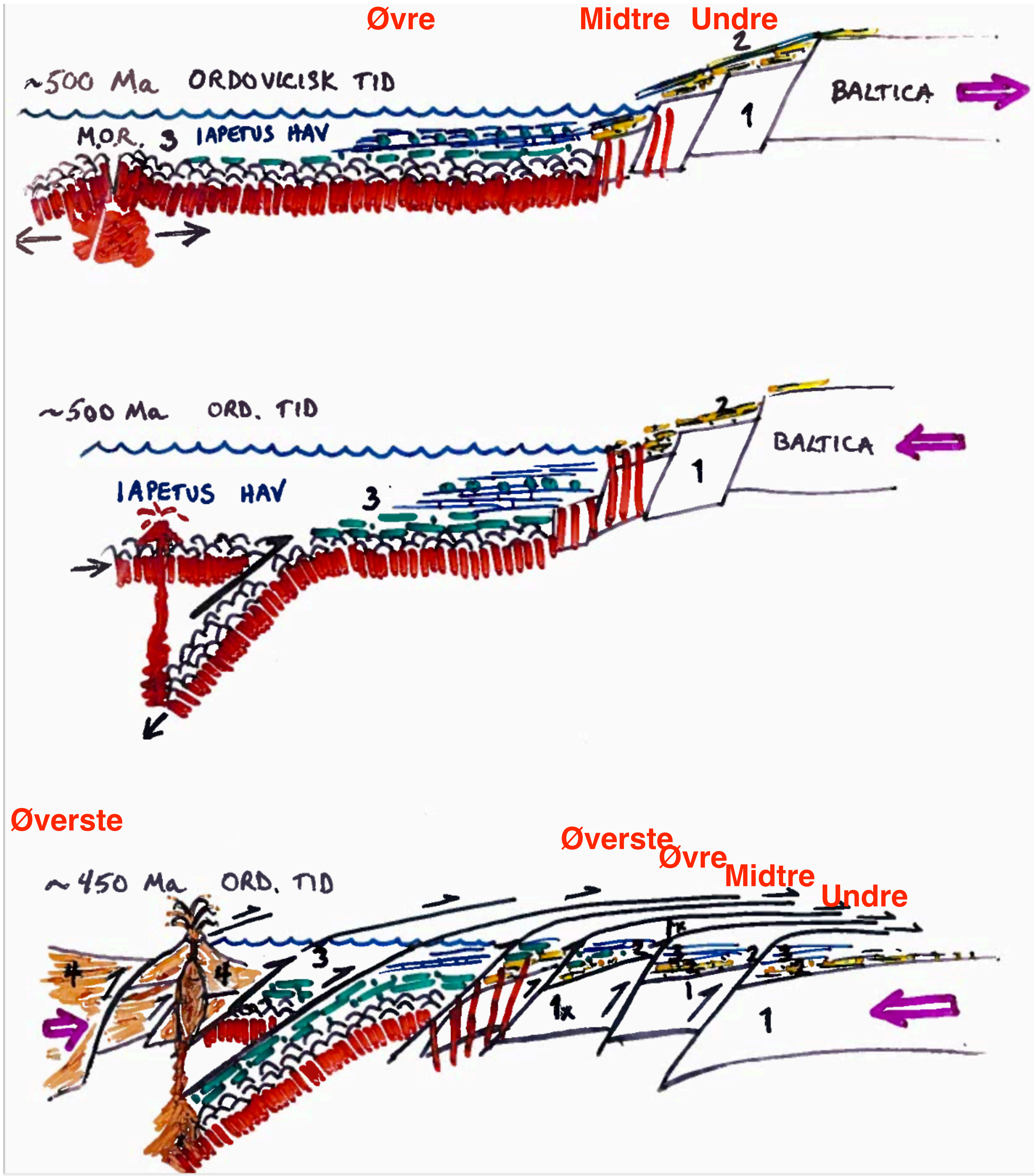
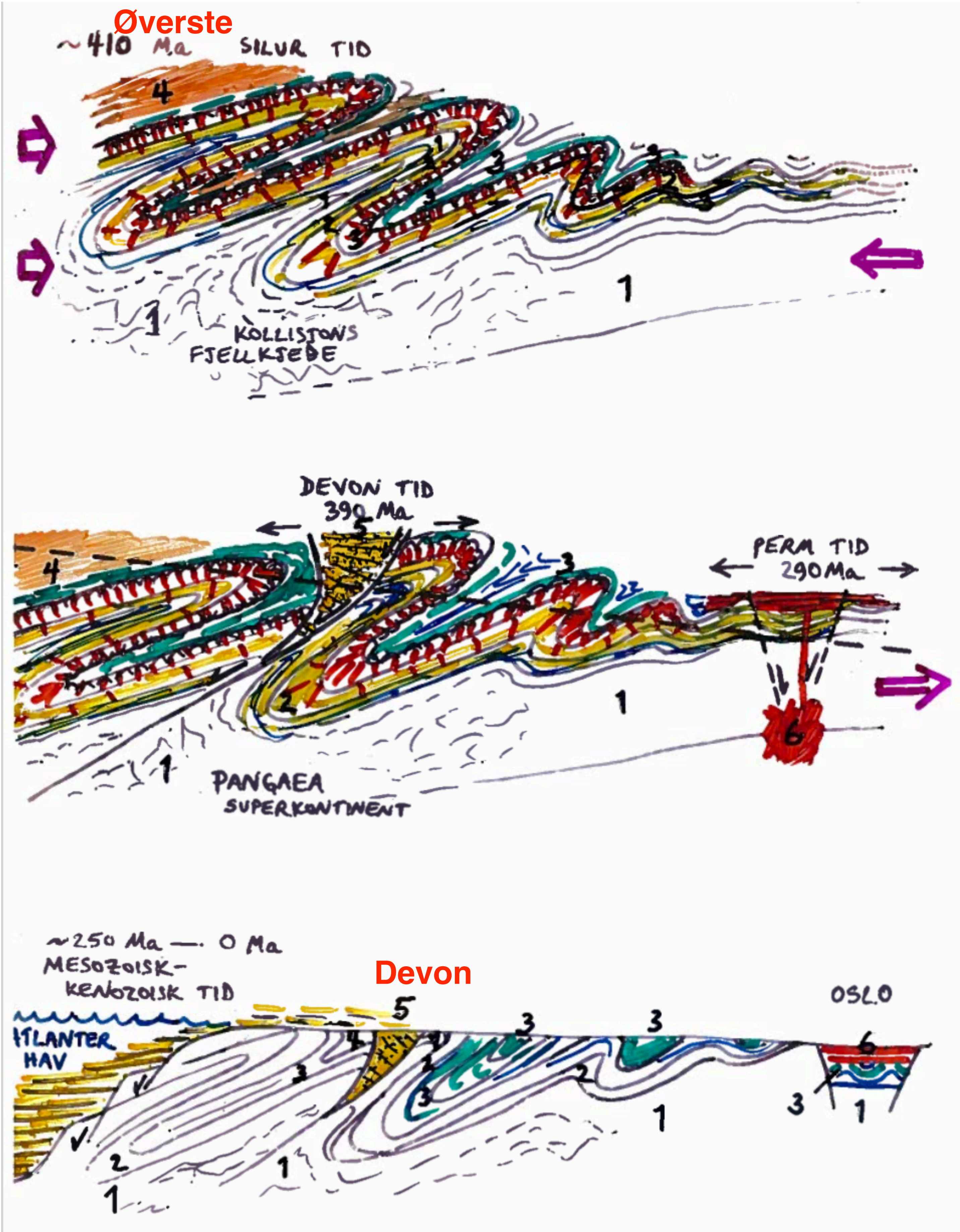

Kaledonsk fjellkjede
Lapland granulitt belte
grønnsteins belter
Svekokarelsk
Svekofennisk
rapakivi granitt
siljan ring
Svekonorvegisk
Øverste
Øvre
Midtre
Undre
Tegnforklaring
Legend
Osloriften; perm - karbon
Oslo Rift (Permian - Carboniferous)
Sedimenter utenfor den kaledonske fjellkjeden (neoproterozoikum-fanerozoikum)
Sediments outside the Caledonian Orogen (Neoproterozoic-Phanerozoic)
Bergarter i den kaledonske fjellkjeden
Rocks within the Caledonian Orogen
Sedimentbasenger i fjellkjeden (seinsilur - devon)
Intermontane basin deposits (Late Silurian - Devonian)
Øverste dekkeserie (neoproterozoikum - ordovicium)
Uppermost Allochthon (Neoproterozoic - Ordovician)
Øvre dekkeserie (neoproterozoikum - silur)
Upper Allochthon (Neoproterozoic - Silurian)
Midtre dekkeserie (mesoproterozikum - cambrium)
Middle Allochthon (Mesoproterozic - Cambrian)
Undre dekkeserie (mesoproterozoikum - paleozoikum)
Lower Allochthon (Mesoproterozoic - Palaeozoic)
Proterozoikum
Proterozoic
Dyp- og overflatebergarter (1700-900 mill. år) - gotisk og svekonorvegisk
Igneous and supracrustal rocks (1 700-900 Ma) - Gothian and Sveconorwegian
Det transskandinaviske intrusivbeltet og rapakivigranitt (1 800-1 650 mill. år)
Transscandinavian Igneous Belt and rapakivi granite (1 800-1 650 Ma)
Dyp- og overflatebergarter (1960-1750 mill. år) - hovedsaklig svekofennisk
Igneous and supracrustal rocks (1 960-1 750 Ma) - mainly Svecofennian
Dyp- og overflatebergarter (2300-1 900 mill. år) - Lapplandgranulittbeltet
Igneous and supracrustal rocks (2300-1 900 Ma) - Lapland Granulite Belt
Overflatebergarter og lagdelte gabbroer (2500-1 950 mill. år) - svekokarelsk
Supracrustal rocks and layered gabbros (2500-1 950 Ma) - Svecokarelian
Arkeikum
Archaean
Dyp og overflatebergarter (3200-2500 mill. år)
Igneous and supracrustal rocks (3200-2500 Ma)


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


Øverste
Øvre
Midtre
Undre
~500 Ma ORDOVICISK TID
M.O.R.
IAPETUS HAV
BALTICA
~500 Ma ORD. TID
IAPETUS HAV
BALTICA
Øverste
~450 Ma ORD. TID
Øverste
Øvre
Midtre
Undre


Øverste
~410 Ma SILUR TID
KOLLISJONS FJELLKJEDE
DEVON TID
390 Ma
PERM TID
290 Ma
PANGAEA SUPERKONTINENT
~250 Ma — 0 Ma
MESOZOISK-KENOZOISK TID
Devon
ATLANTERHAV
OSLO

# Metamorfe bergarter

## de fleste bergarter i Norge er metamorfe

**(på norsk sier man ikke *metamorfisk,* vi snakker ikke om *fisk*)**

**Geologer sier at det finnes 3 bergartsgrupper:**

**1 Magmatiske ba.** **(engelsk *Igneous rocks*)**
**2 Sedimentære ba.** **(*Sedimentary rocks*)**
**3 Metamorfe ba.** **(*Metamorphic rocks*)**

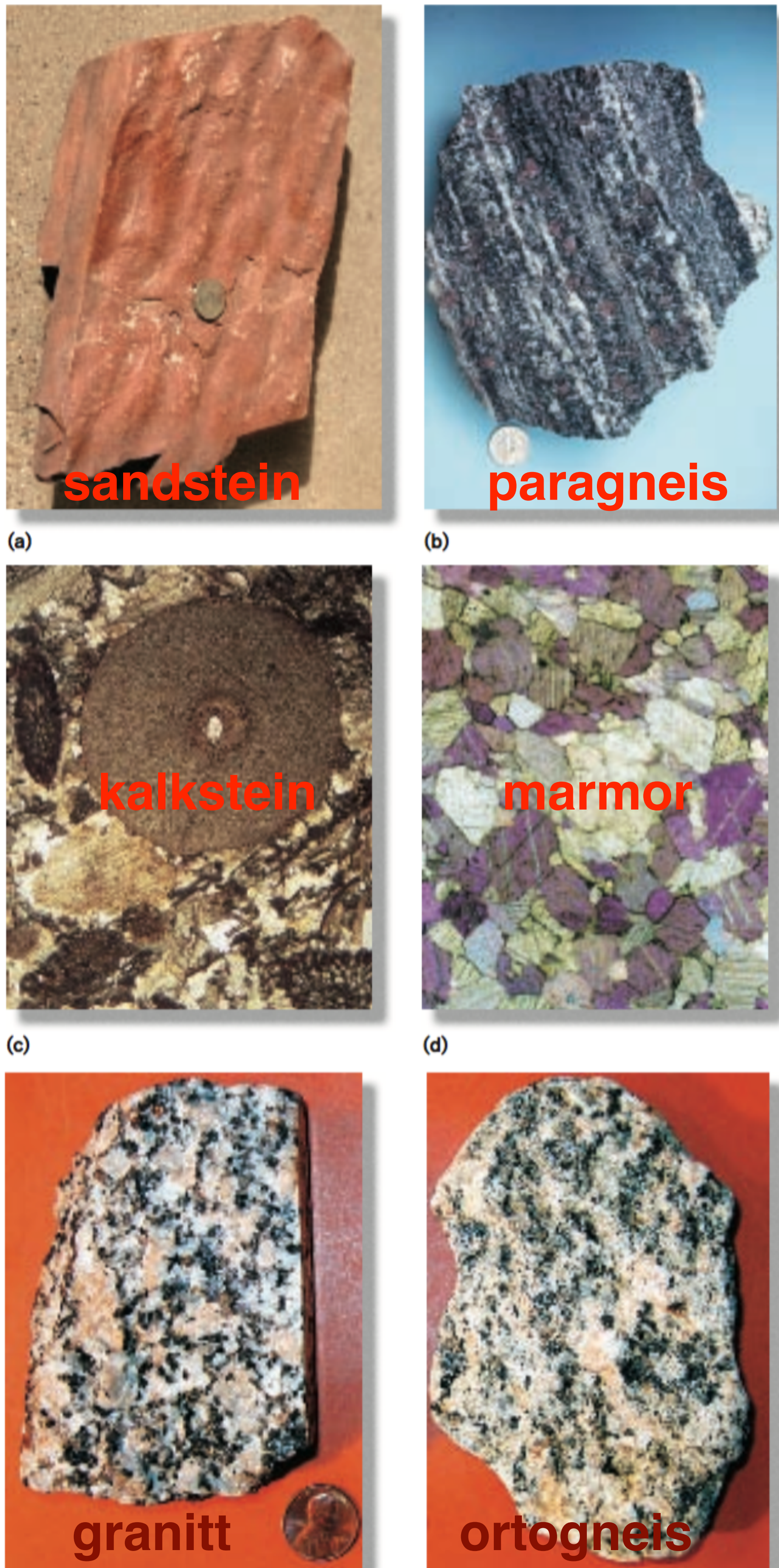
**Men alle ba. var opprinnelig enten 1 eller 2.**

**den opprinnelig bergart (1, 2) kalles for "protolitt"**

Protolit betyr

Ba. FØR metamorfose → Metamorf ba.

**Protolith → Metamorphic rock**




(a) (b) (c) (d) (e) (f)

**FIGURE 8.1** **(a)** Hand specimens of red shale, consisting of clay flakes, quartz, and iron oxide (hematite). **(b)** Hand specimen of metamorphic rock (gneiss) containing biotite, quartz, feldspar, and bright purple garnets. A rock similar to the shale could have been the protolith of this gneiss. This hand specimen is about 10 cm wide. **(c)** This thin section of a Devonian limestone shows that the rock consists of small fossil shells and shell fragments that have been cemented together. The field of view is about 3 mm. **(d)** This thin section of marble shows how new crystals of metamorphic calcite grew to form an interlocking texture. This photo is taken with polarized light; the color and darkness of an individual grain depends on its orientation with respect to the light waves. **(e)** Granite has randomly oriented grains. **(f)** Metamorphosed granite has flattened and aligned grains.

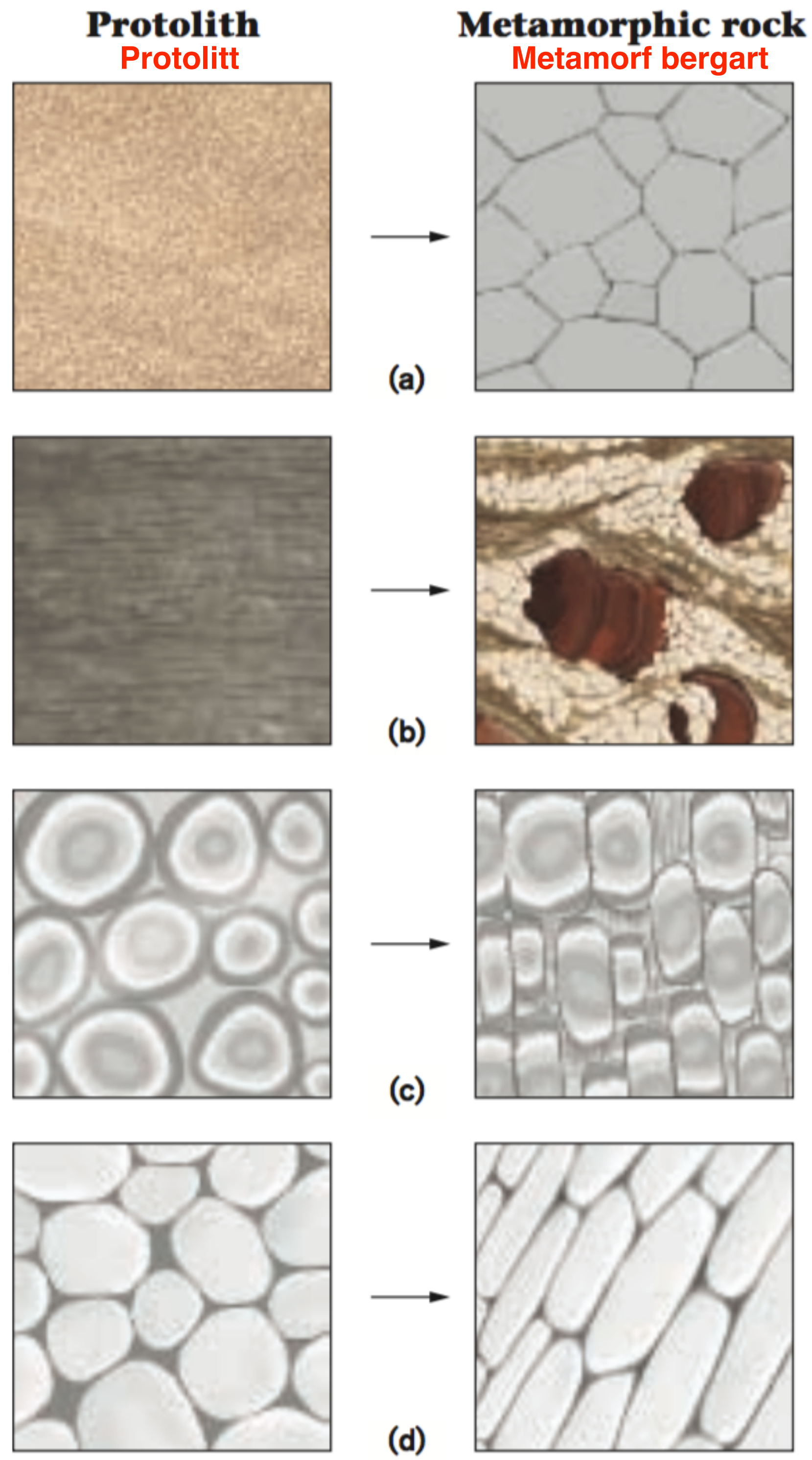
(man sier IKKE "metamorfisk" på norsk
man sier <u>metamorfe</u>)

(man sier IKKE "metamorfisme" på norsk.
man sier <u>metamorfose</u>)

("paragneis")
gneis fra sedimentær ba.

marmor (fossiler til venstre, kalsitt krystaller til høyre)
tynnslipp

("ortogneis")
gneis fra magmatisk ba.




tynnslipp

**FIGURE 8.2** Examples of protoliths and metamorphic rocks derived from them, illustrating different mechanisms of metamorphism. Each box contains a sketch of a thin section, with the field of view about 1 mm wide. **(a)** A protolith of siltstone recrystallizes to form metamorphic rock made of larger quartz crystals of the same mineral. **(b)** Metamorphic reactions (neocrystallization) in a protolith of silty shale will form a rock formed of quartz, mica, large garnets, and other minerals. **(c)** A protolith of oolitic limestone (an oolite is a tiny snowball-like sphere of calcite with internal concentric rings) undergoes pressure solution so that grains have dissolved on two sides. **(d)** A protolith of quartz sandstone deforms plastically to produce a metamorphic rock in which the quartz grains have been flattened into wavy pancakes.

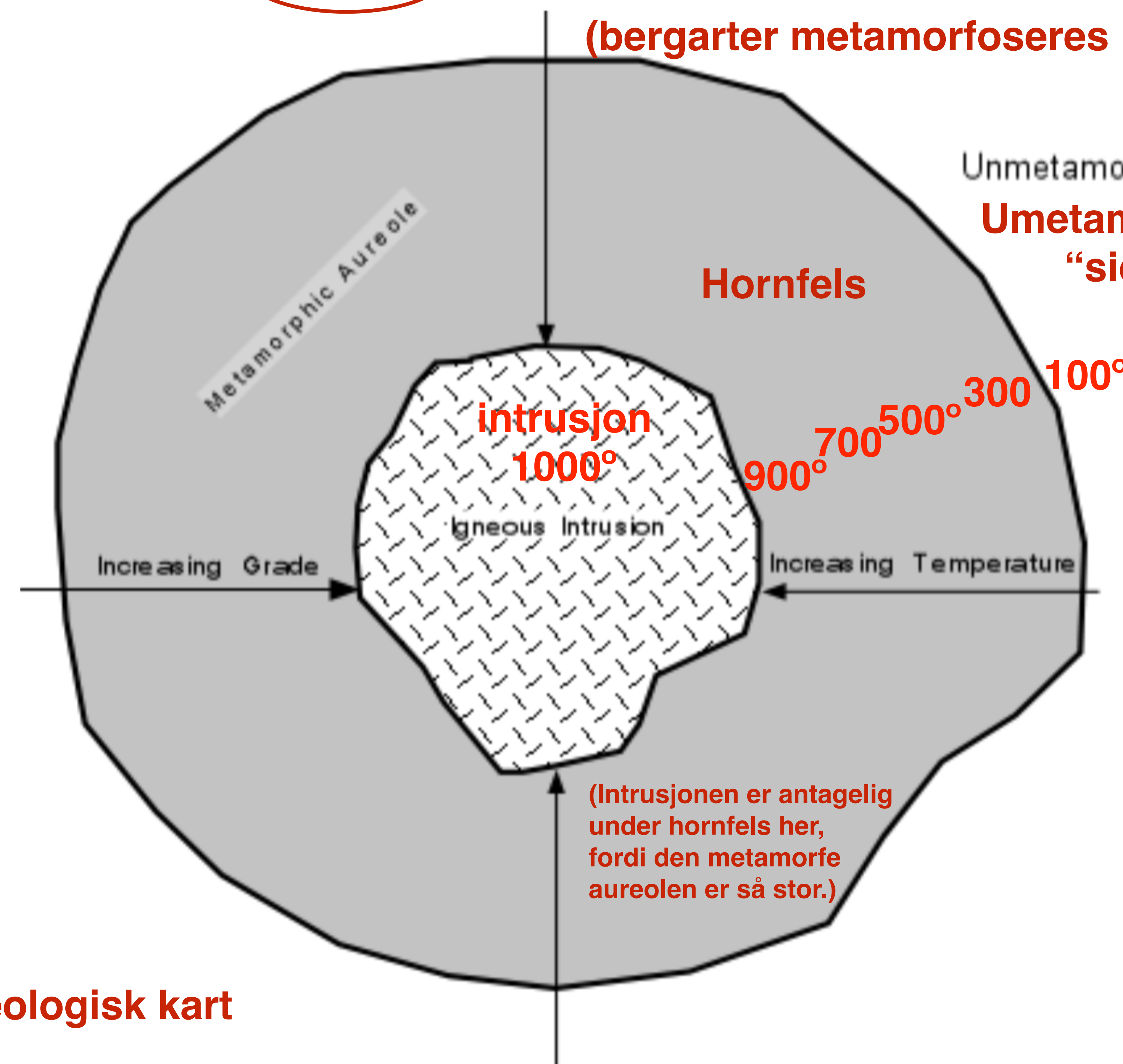
**den enklest typ metamorfose**

Nelson.pdf (page 64 of 248)

foliation, called a ***hornfels***.

# "Kontakt metamorfose"

## (bergarter metamorfoseres i kontakt med magma)



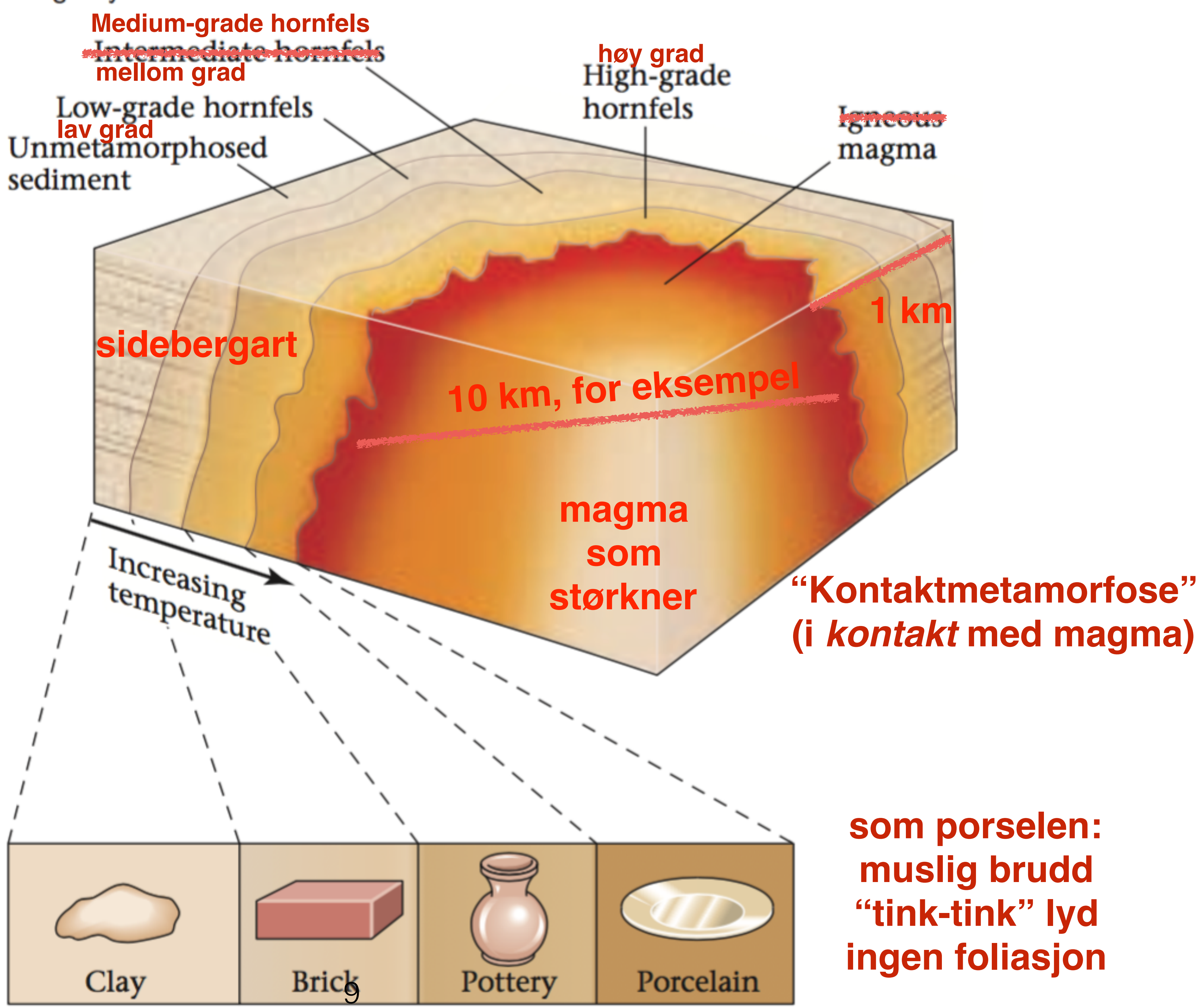

**geologisk kart**

aureol

subst. -en, -er

lyskrans rundt sol el. måne pga. lysstrålenes avbøyning i skylag

**FIGURE 8.23** In a metamorphic aureole bordering an igneous intrusion, the highest-grade thermally metamorphosed rocks directly border the intrusion. The grade decreases away from the pluton. The gradation is analogous to the gradation from clay to pottery to porcelain, obtained by firing clay in an oven.

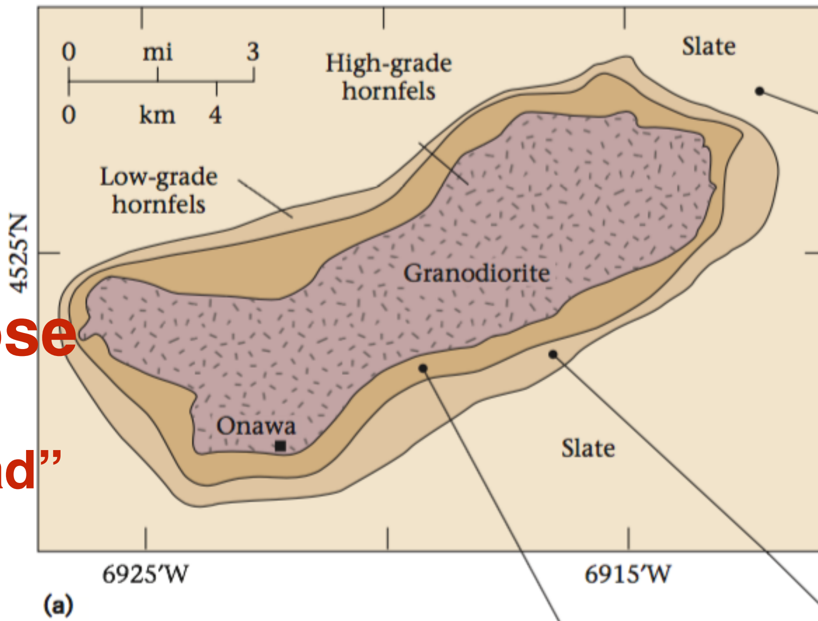



som porselen:
muslig brudd
"tink-tink" lyd
ingen foliasjon

Marshak.pdf (page 273 of 957)

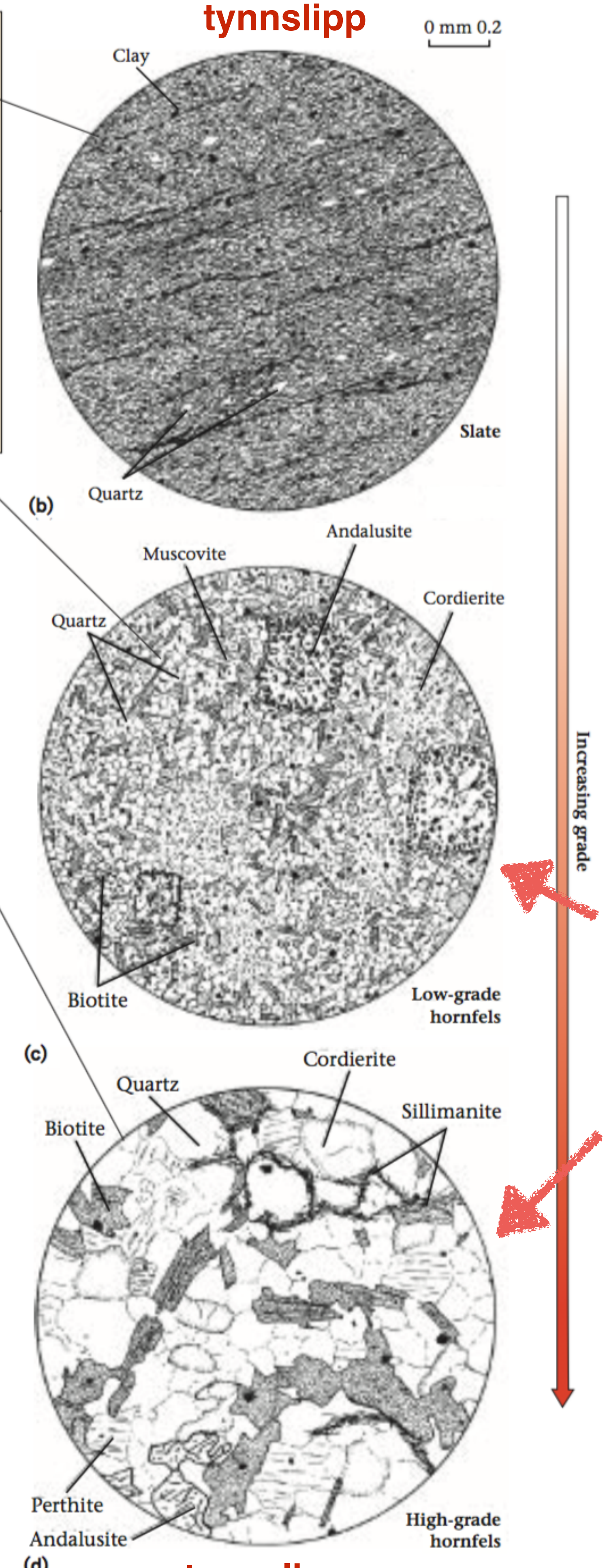
## kontaktmetamorfose

**økende metamorf "grad" mot intrusjonen**




GURE 8.24 The metamorphic aureole around the
ıawa Pluton, Maine. **(a)** The width of the preserved aureole
ries with location, as seen on this map of the pluton. The
ange in rock texture can be seen by comparing the following
etches of the three photomicrographs. Each sketch shows the
neral grains visible. (Not all of the labeled minerals are discussed
this book.) **(b)** Far from the pluton, the country rock is a slate
nsisting of aligned clay and very fine quartz. The thin, darker bands
present cleavage. **(c)** In the low-grade part of the aureole, a totally
w hornfels texture has formed. This sample contains larger crystals of
artz, biotite, muscovite, andalusite, and other minerals. **(d)** In the high-
ade part of the aureole, the hornfels is much coarser and contains
ferent minerals. The muscovite has vanished, and this sample contains
ge crystals of biotite, quartz, sillimanite, andalusite, and other minerals.
ıte that there is no preferred mineral orientation in hornfels.

**tynnslipp**




**tynnslipp**

**Ikke metamorf. $S_0$ svak men synlig.**

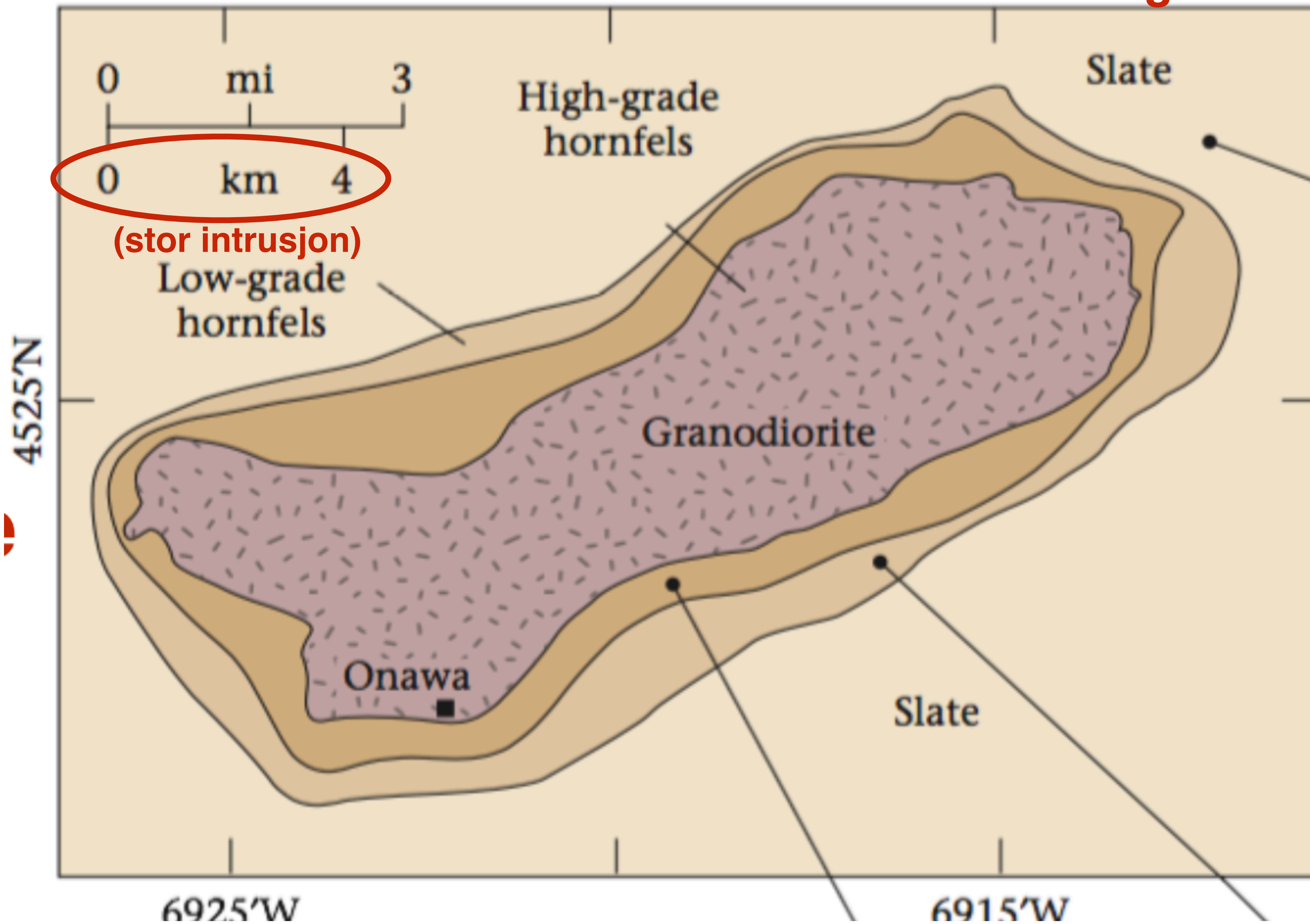
**lav grad**

**ingen foliasjon (S1), fordi kontakt metamorfose er statisk, ikke dynamisk**

**høy grad**

**Geologer ser etter spesielle mineraler for å bestemme metamorf grad av hornfels.**

Marshak figur

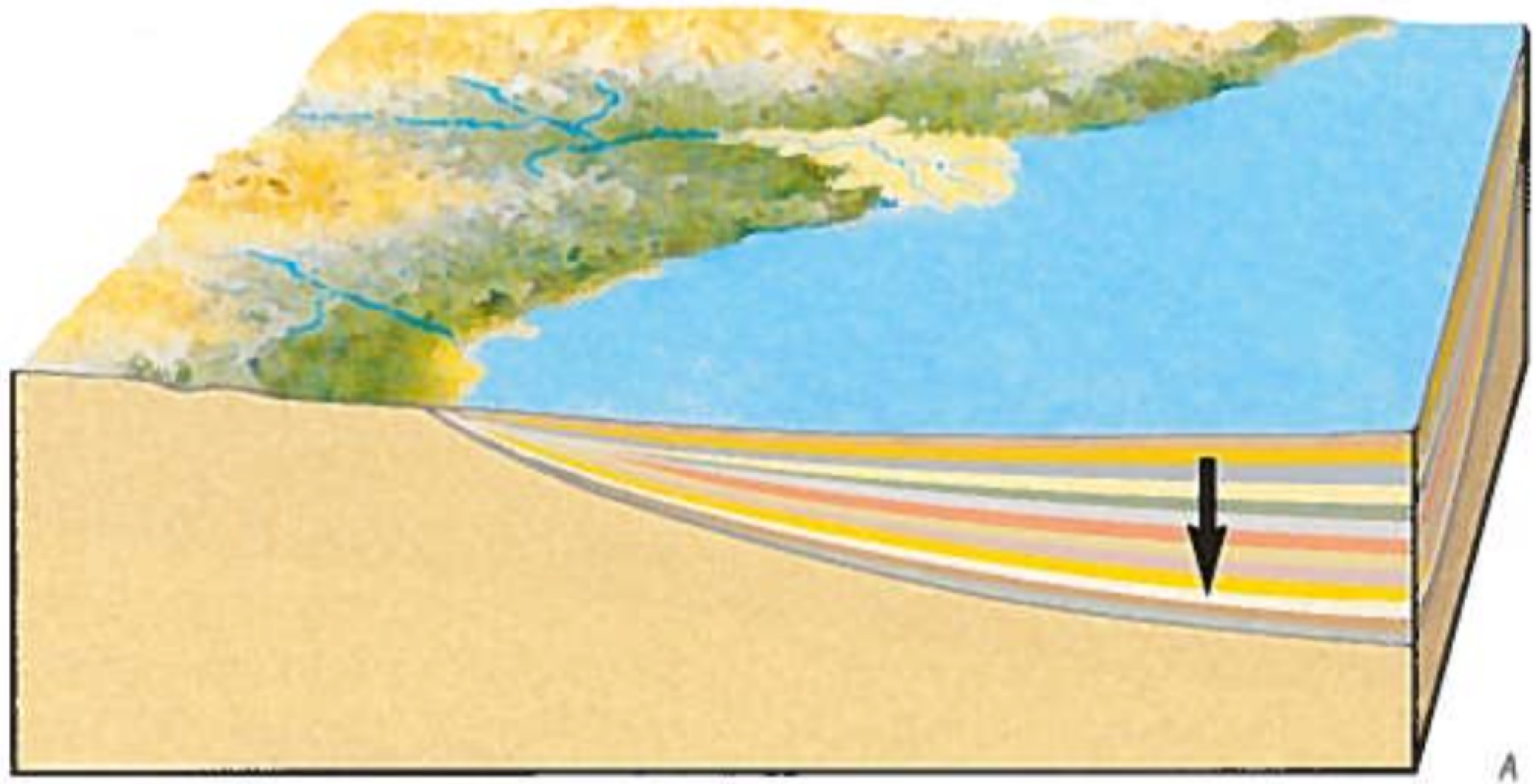



Ikke metamorf

Høy grad

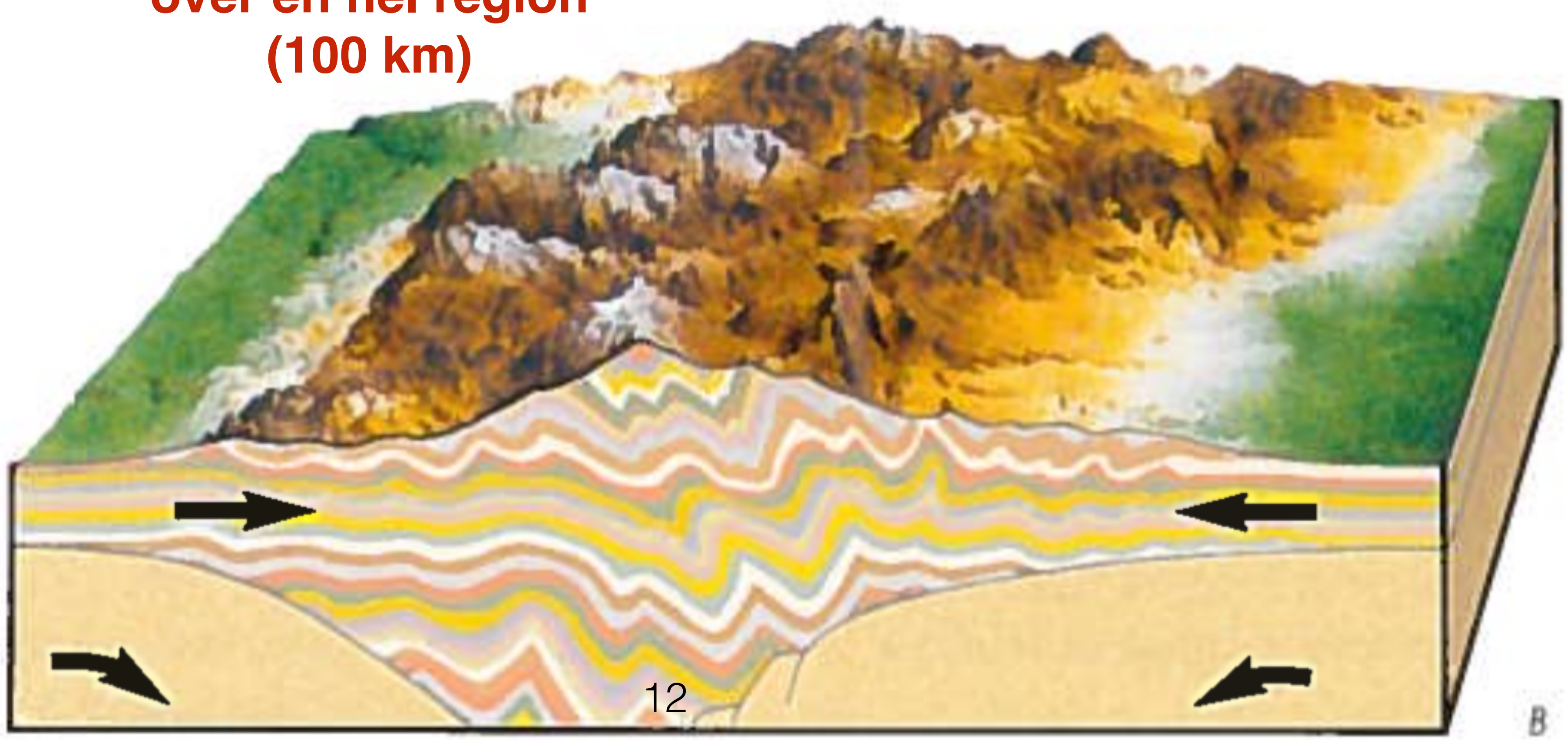
Lav grad

**Typisk hornfels aureole er ca. 1 km tykk**



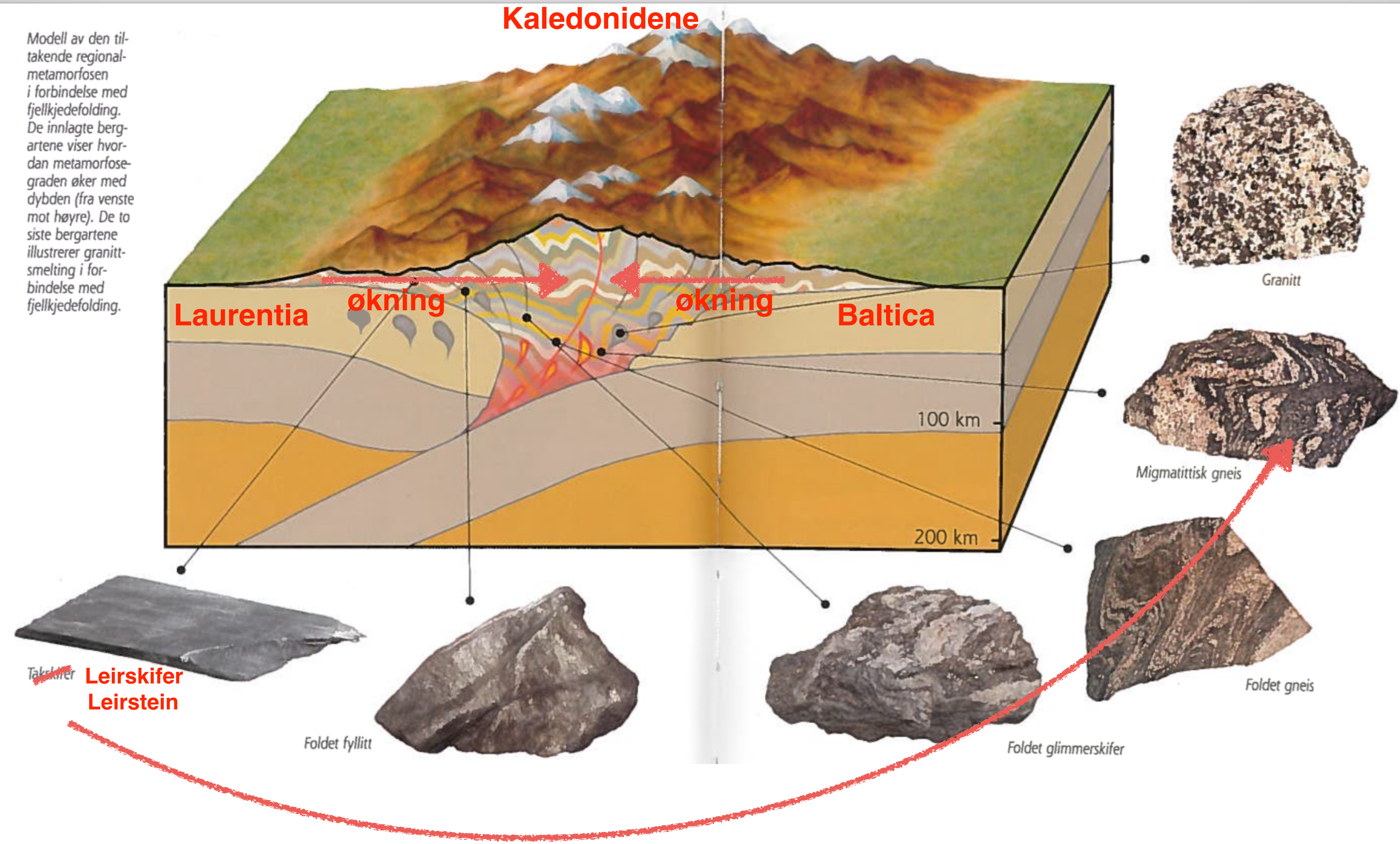

*To figurer som illustrerer forskjellen mellom A, det vertikale trykket som sedimenter utsettes for og som fører til sammepressing og sammenkitting, og B, det differensielle trykket som bergartene utsettes for i forbindelse med en fjellkjedefolding*

**"Regionalmetamorfose"**
**over en hel region (100 km)**



# "Regionalmetamorfose"



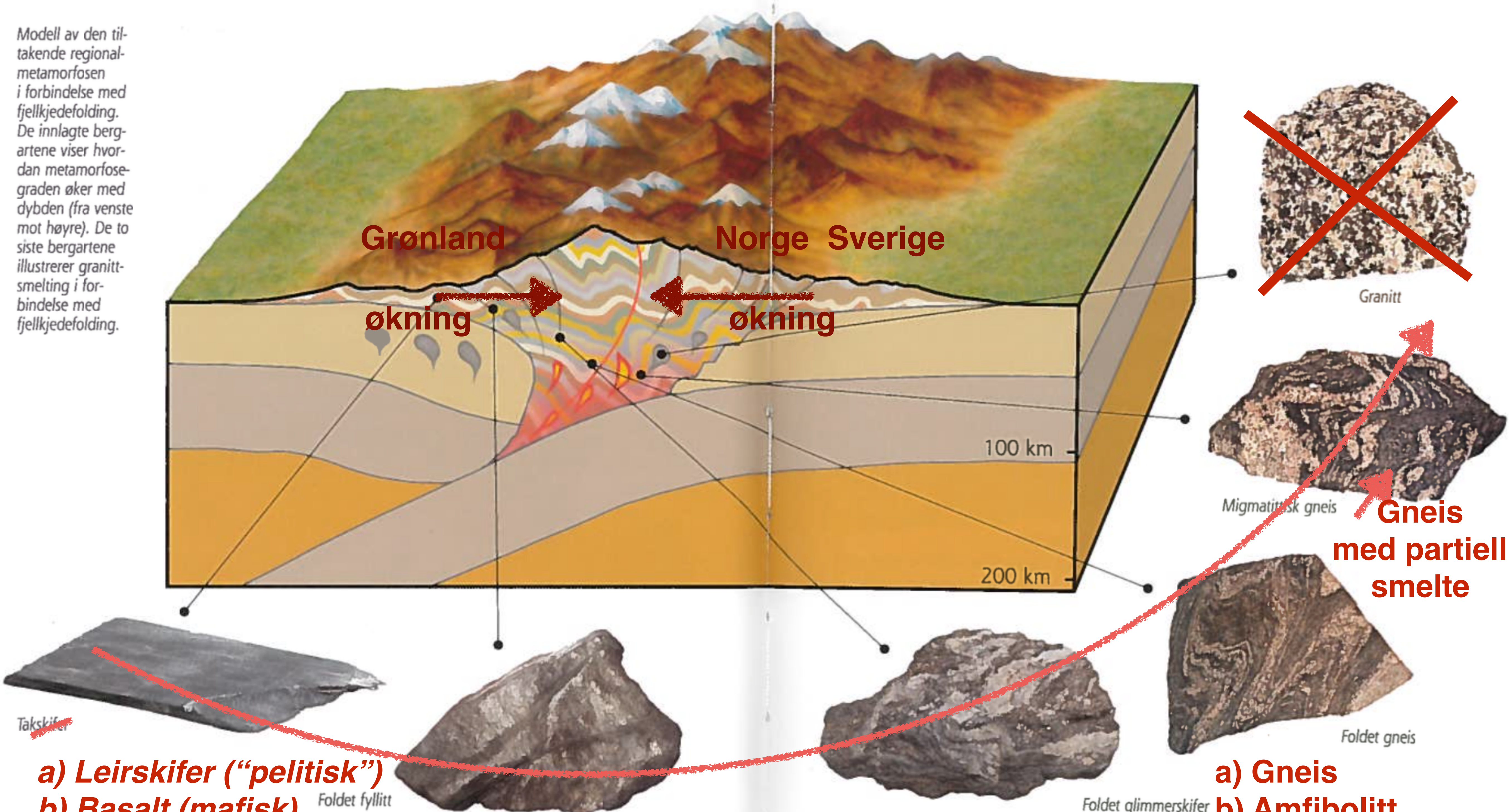



**økende grad over en region, øker ofte mot midten av en fjellkjede**

# Regionalmetamorfose: økende grad over en hel region, ofte mot midten av en fjellkjede

Schou Jensen.pdf (page 90 of 112)

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) Leirskifer ("pelitisk")*
*b) Basalt (mafisk)*
*c) Kalkstein*
*d) Granitt*

a) Fyllitt,
b) Grønnstein
c) Kalkstein/marmor
d) Granitt

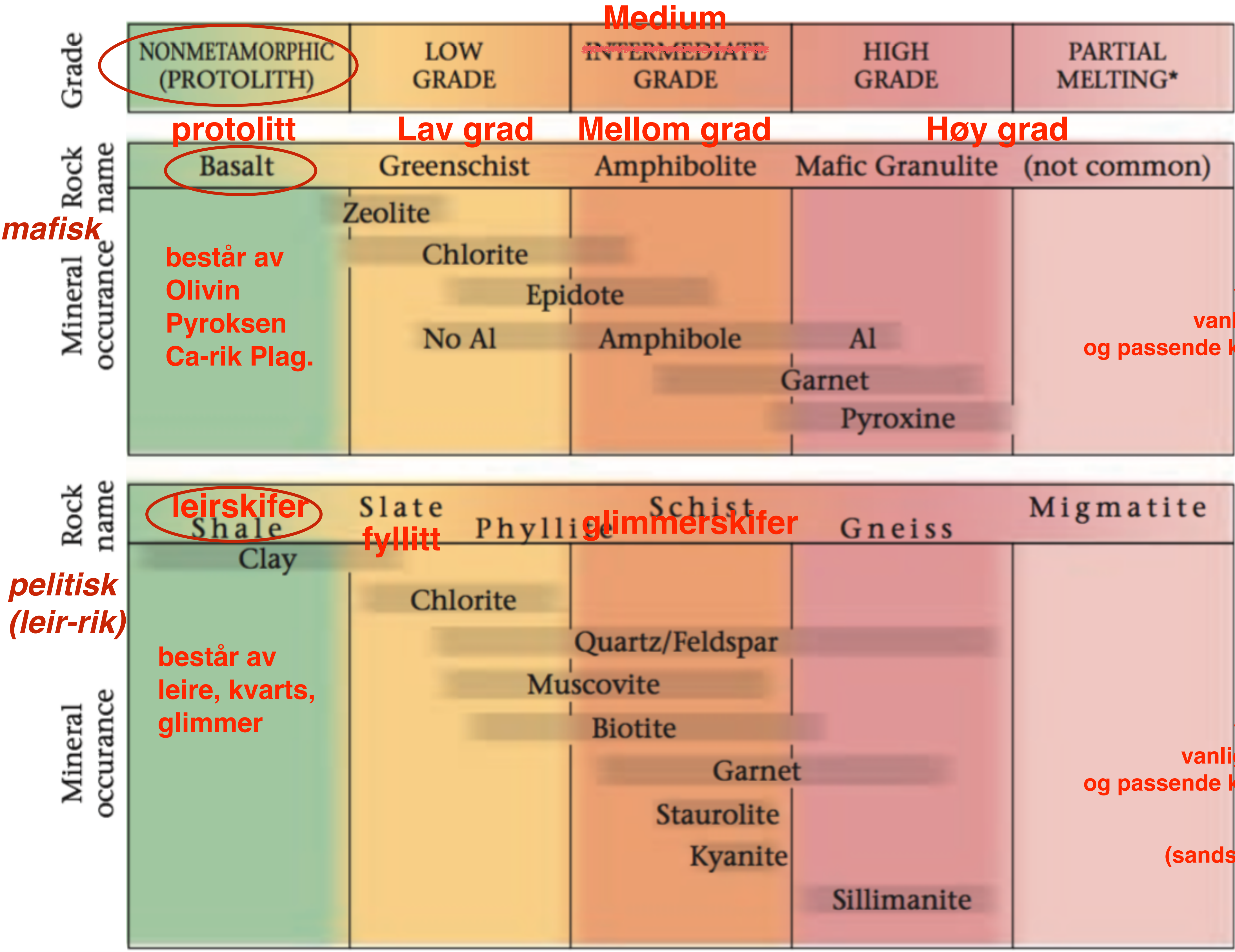
a) Glimmerskifer
b) Amfibolitt
c) Marmor
d) Gneis

a) Gneis
b) Amfibolitt
c) Marmor
d) Gneis

a -> a -> a -> a
b -> b -> b -> b
osv.

(Metamorfosegrad og deformasjon øker nordvestover fra Trondheim. Nærmere kollisjons-sonen.)

Marshak.pdf (page 267 of 957) **viser mineraler som vokser under metamorfose ved ulike grader**




*Note: The temperature at which partial melting depends on rock composition and water content. Mafic rocks begin to melt at higher temperatures than do pelitic rocks. Wet rocks melt at lower temperatures than do dry rocks.

(b)

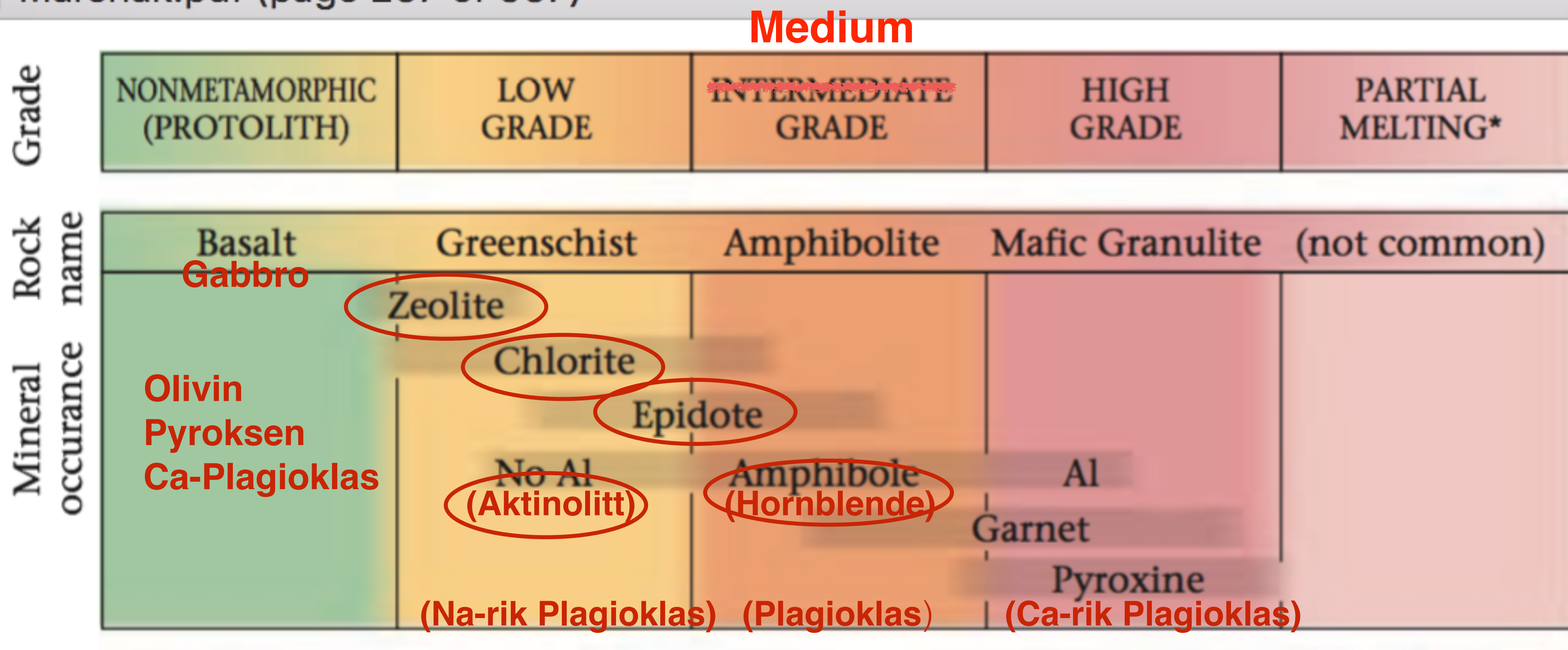
Basalt er verdens mest vanlig magmatisk ba. og passende kjemi for spesielle mineraler

(granitt har kjedelig kjemi)

Leirskifer er verdens mest vanlig sedimentære ba. og passende kjemi for spesielle mineraler

(sandstein har kjedelig kjemi)

Marshak.pdf (page 267 of 957)




Oval rundt mineraler som har vann (OH) i gitter.

Ingen vann i basalt

Mye vann i grønnskifer

Noe vann i amfibolitt

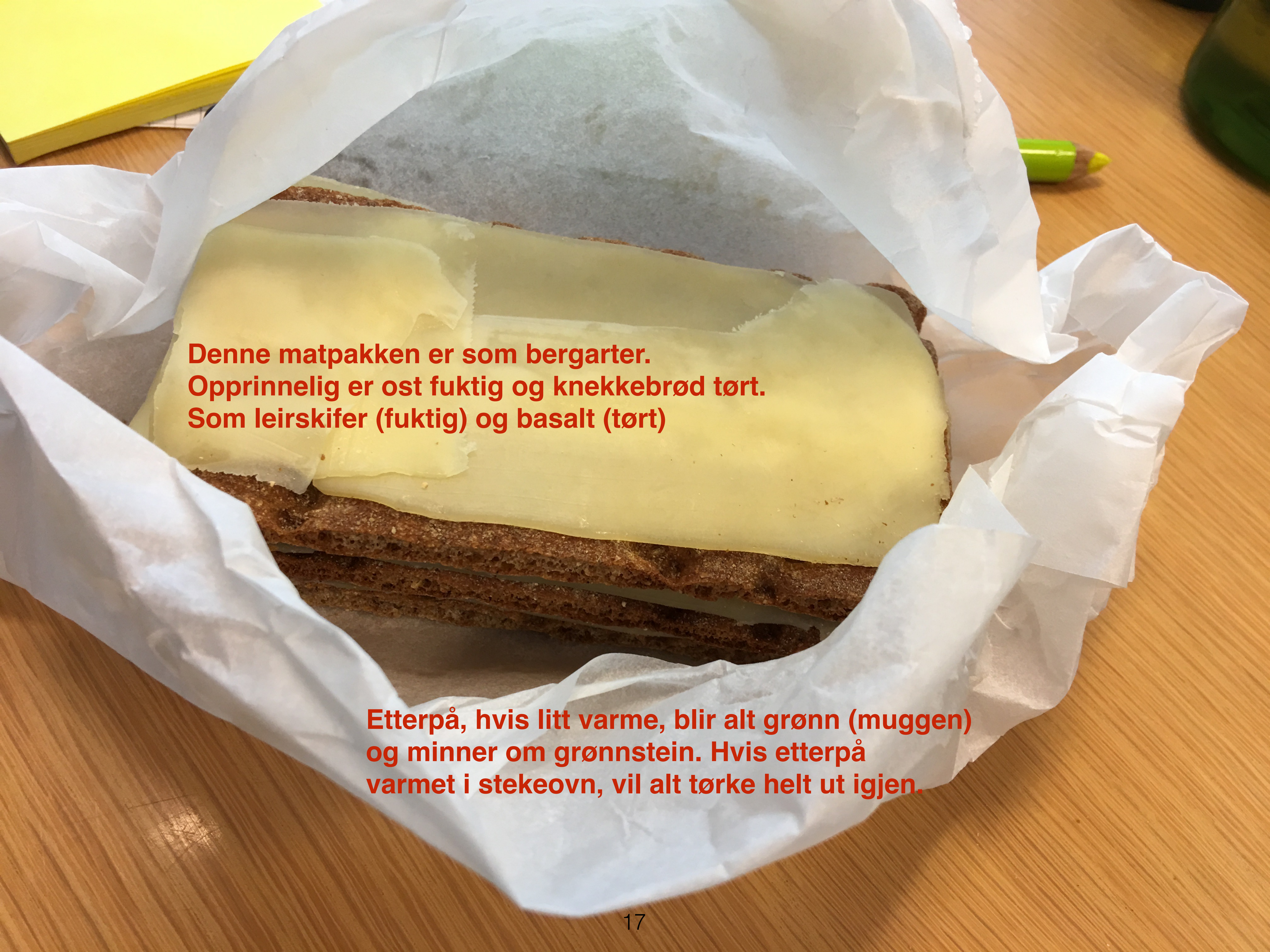
Ingen vann i granulitt

Hvis det er nok vann, så blir det partiell smelte.

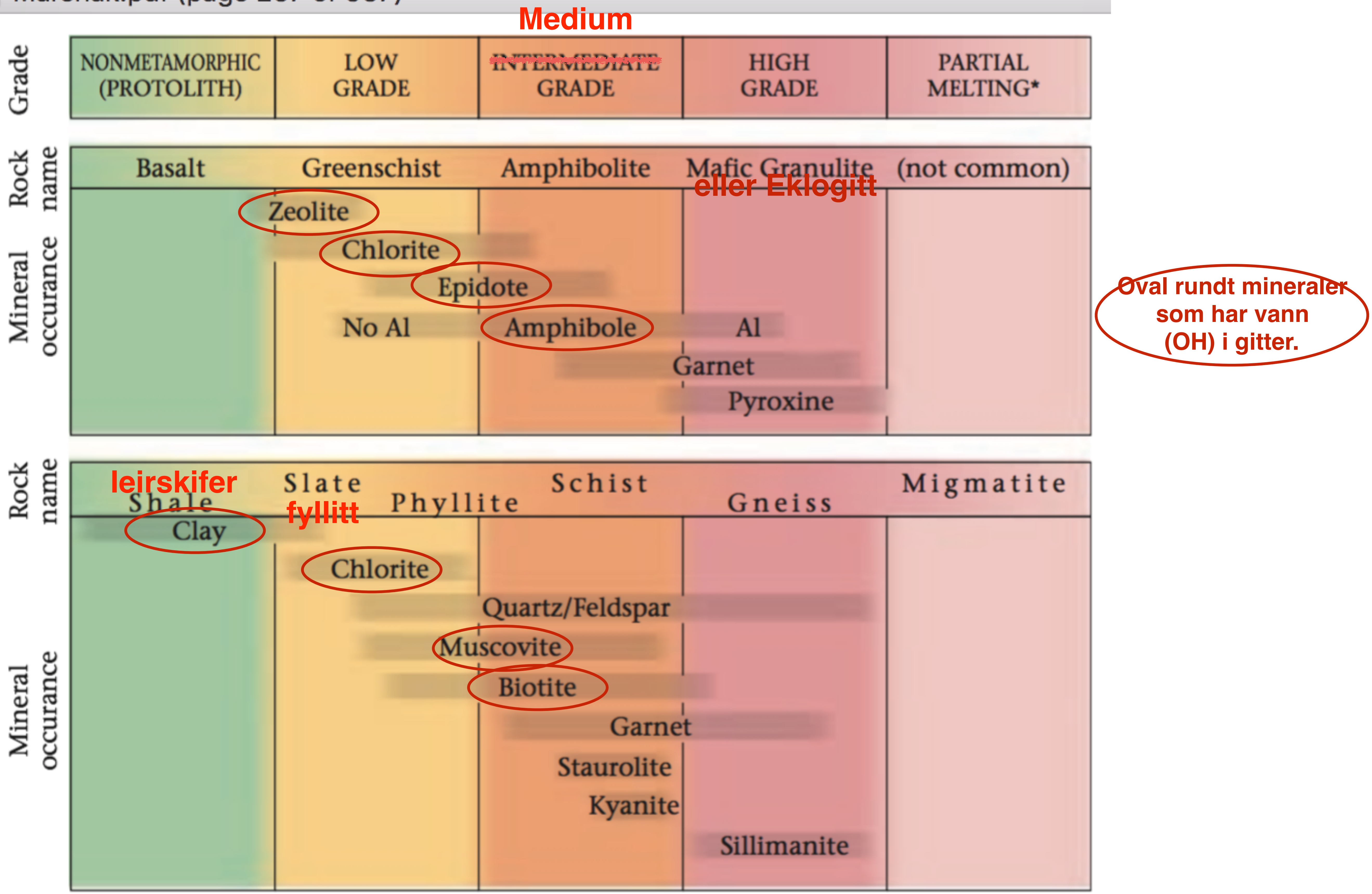
Basalt er svart.

Kloritt, epidot, og Aktinolitt er alle grønne. Derfor er grønnskifer grønn.

Hornblende er svart. Derfor er amfiblitt svart og ikke grønn.


Denne matpakken er som bergarter.
Opprinnelig er ost fuktig og knekkebrød tørt.
Som leirskifer (fuktig) og basalt (tørt)
Etterpå, hvis litt varme, blir alt grønn (muggen)
og minner om grønnstein. Hvis etterpå
varmet i stekeovn, vil alt tørke helt ut igjen.

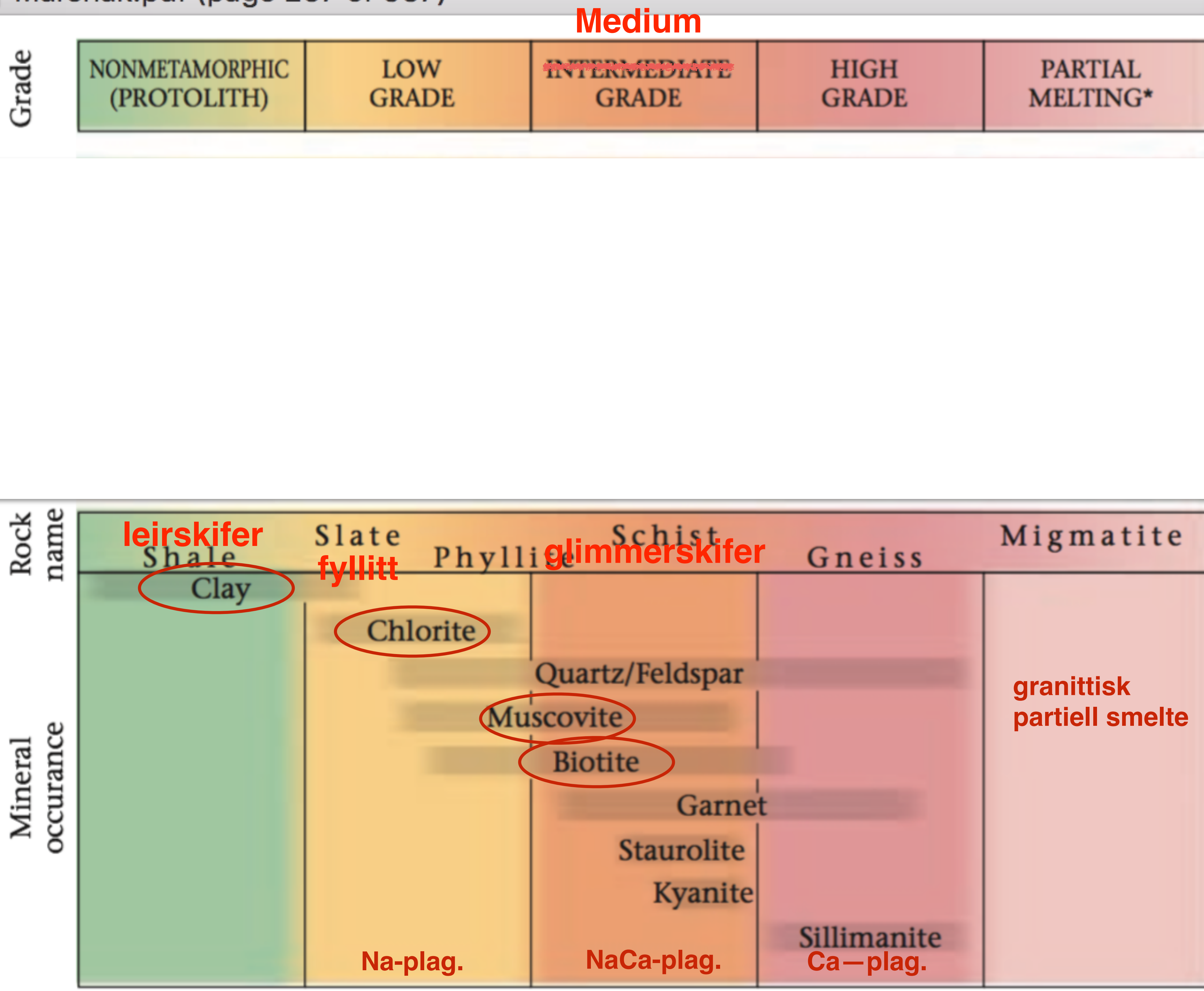
Marshak.pdf (page 267 of 957)




*Note: The temperature at which partial melting depends on rock composition and water content. Mafic rocks begin to melt at higher temperatures than do pelitic rocks. Wet rocks melt at lower temperatures than do dry rocks.

(b)

Marshak.pdf (page 267 of 957)

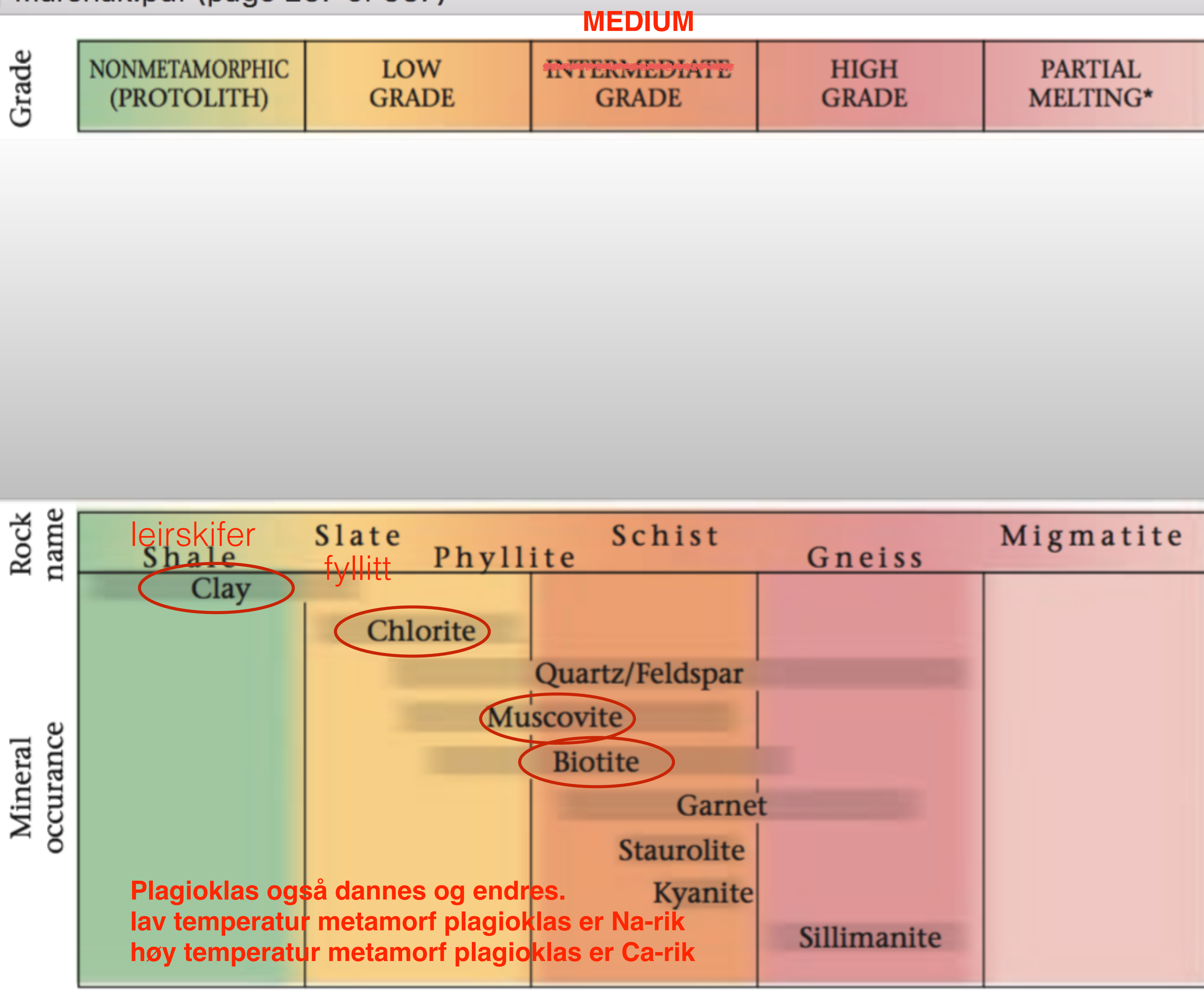



Oval rundt mineraler som har vann (OH) i gitter.

*Note: The temperature at which partial melting depends on rock composition and water content. Mafic rocks begin to melt at higher temperatures than do pelitic rocks. Wet rocks melt at lower temperatures than do dry rocks.

(b)

Marshak.pdf (page 267 of 957)

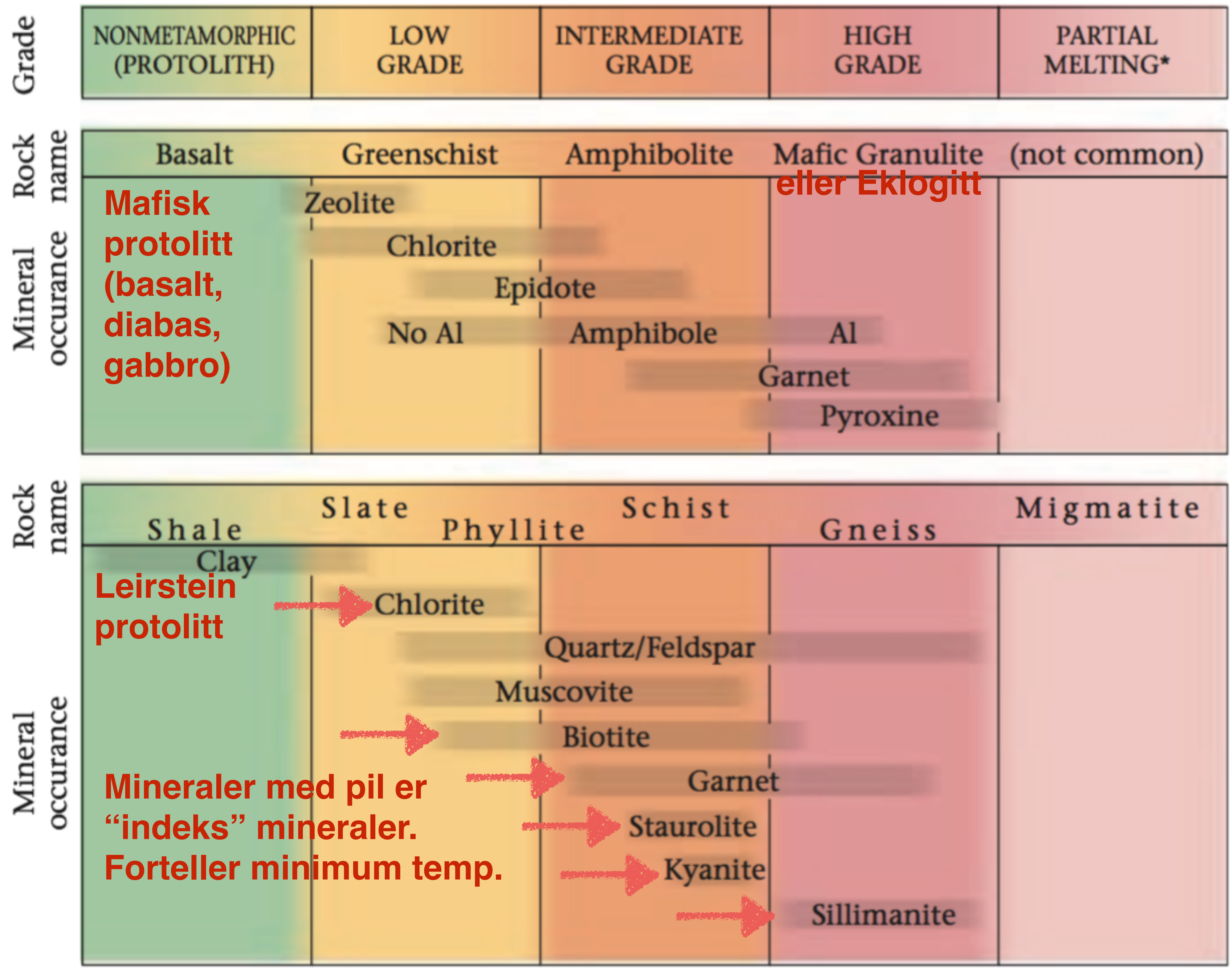



Oval på mineraler med vann. Biotitt overlever ved høy grad, men andre våtte mineraler ikke

*Note: The temperature at which partial melting depends on rock composition and water content. Mafic rocks begin to melt at higher temperatures than do pelitic rocks. Wet rocks melt at lower temperatures than do dry rocks.

(b)

Marshak.pdf (page 267 of 957)




*Note: The temperature at which partial melting depends on rock composition and water content. Mafic rocks begin to melt at higher temperatures than do pelitic rocks. Wet rocks melt at lower temperatures than do dry rocks.

(b)

en.wikipedia.org/wiki/Victor_Goldschmidt

# Victor Goldschmidt

From Wikipedia, the free encyclopedia

*For other uses, see Victor Goldschmidt (disambiguation).*

**This article has multiple issues.** Please help **improve it** or discuss these issues on the **talk page**. [hide]

*(Learn how and when to remove these template messages)*

- This article's **factual accuracy is disputed**. *(December 2012)*
- The **neutrality of this article is disputed**. *(December 2012)*

**Victor Moritz Goldschmidt** ForMemRS[1] (Zürich, January 27, 1888 – March 20, 1947, Oslo)[2][3][4][5] was a mineralogist considered (together with Vladimir Vernadsky) to be the founder of modern geochemistry and crystal chemistry, developer of the Goldschmidt Classification of elements.

**Contents** [hide]



## Early life and career [ edit ]

Goldschmidt was born in Zürich. His Jewish parents, Heinrich Jacob Goldschmidt and Amelie Koehne named their son after a colleague of Heinrich, Victor Meyer. There was a history of great scientists and philosophers in both families. The Goldschmidt family came to Norway 1901 when Heinrich Goldschmidt took over a chair as Professor of Chemistry in Kristiania (Oslo).

Goldschmidt's first important contribution was within the field of geology and mineralogy. His two first larger works were his doctoral thesis *Die Kontaktmetamorphose im Kristianiagebiet* and *Geologisch-petrographische Studien im Hochgebirge des südlichen Norwegens.*

**Victor Moritz Goldschmidt**

Young Victor Goldschmidt

| | |
|---|---|
| **Born** | January 27, 1888<br>Zürich, Switzerland |
| **Died** | March 20, 1947 (aged 59)<br>Oslo, Norway |
| **Fields** | Geochemistry |
| **Institutions** | University of Oslo |
| **Alma mater** | University of Oslo |
| **Thesis** | *Die Kontaktmetamorphose im Kristianiagebiet and Geologisch-* |

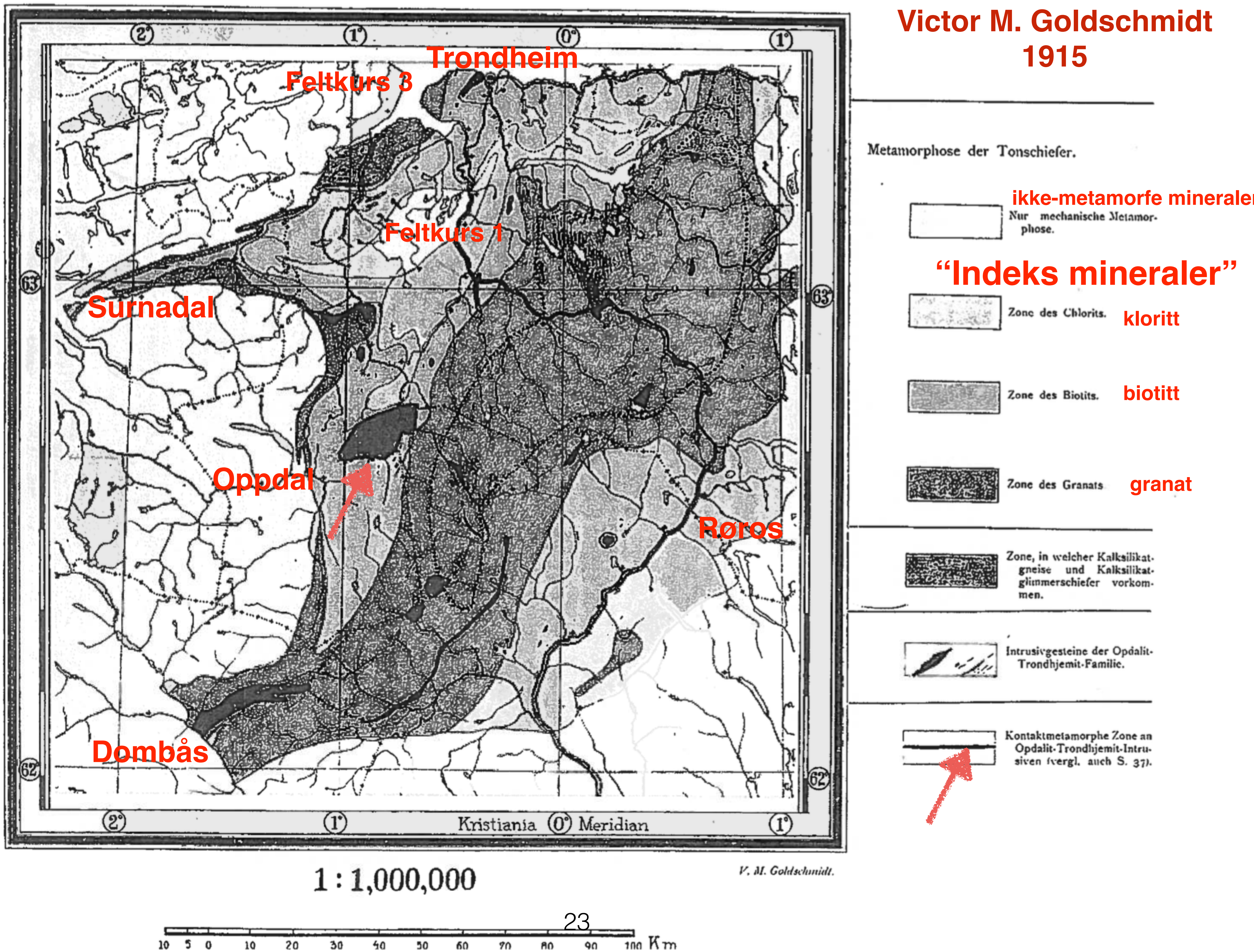
**Verdens første kart over "regionalmetamorfose"**
(og "kontaktmetamorfose" ved Oppdal)

Vid.-Selsk. Skr. I. M.-N. Kl. 1915. No. 10.

(Feltkurs 2 var ca. her)

Taf. II.

# Victor M. Goldschmidt 1915

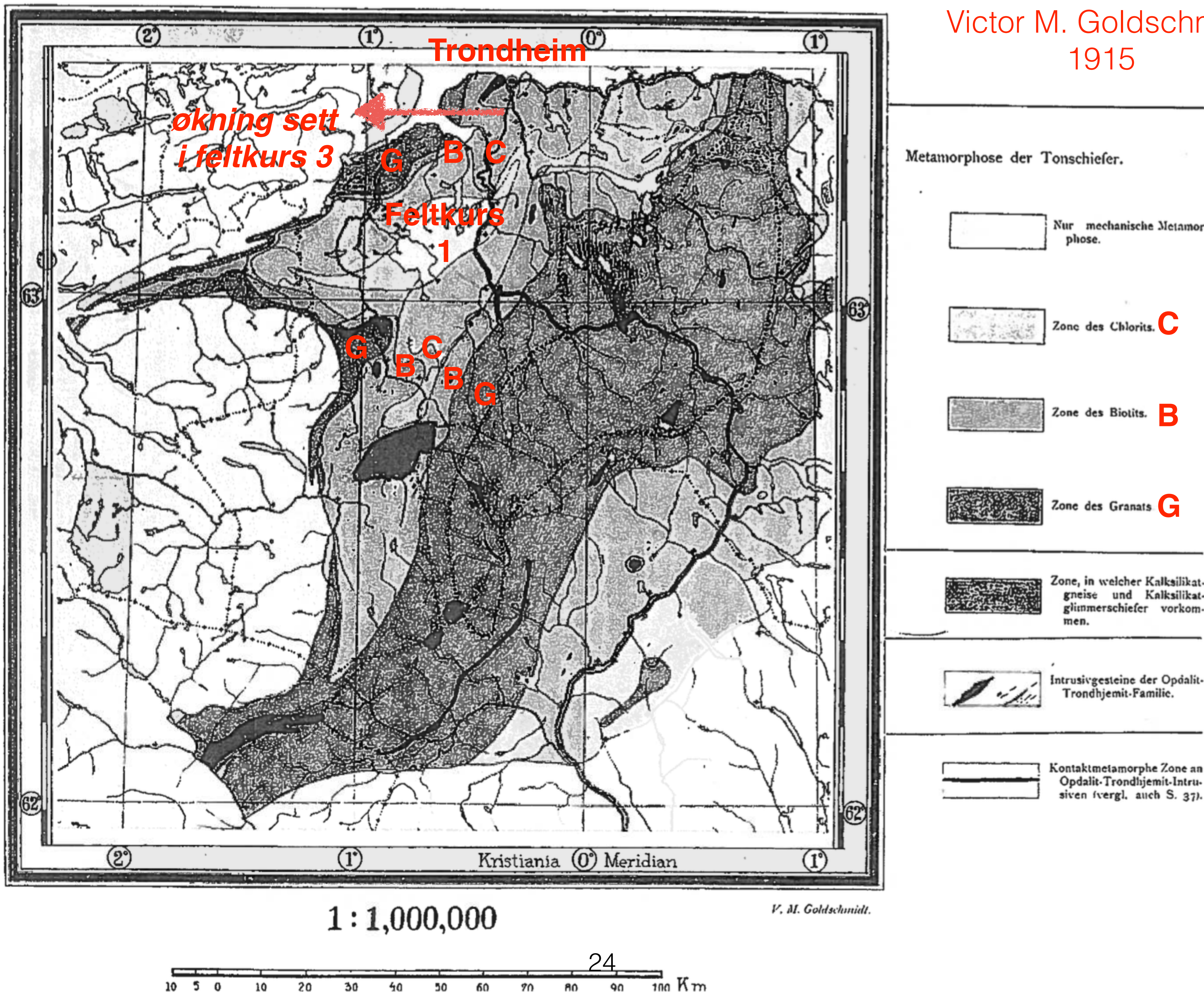


# Verdens første kart med regionalmetamorfe soner

Vid.-Selsk. Skr. I. M.-N. Kl. 1915. No. 10.

Taf. II.

Victor M. Goldschmidt
1915



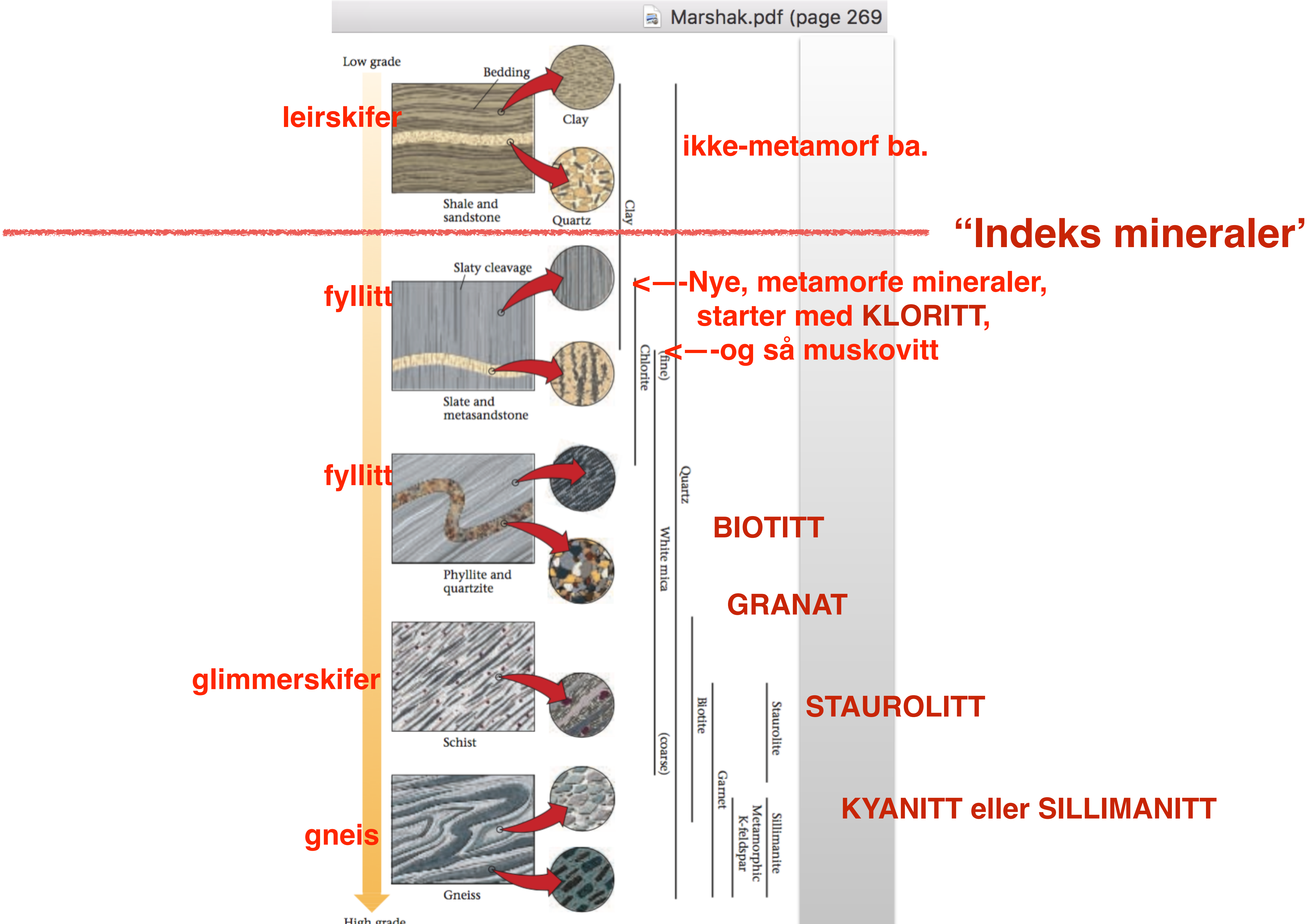



**FIGURE 8.19** When shale progressively metamorphoses from low grade to high grade, it first becomes slate, then phyllite, then schist, then gneiss. In many cases, gneiss and schist can form under the same conditions. The side graph shows the stability range of various minerals.

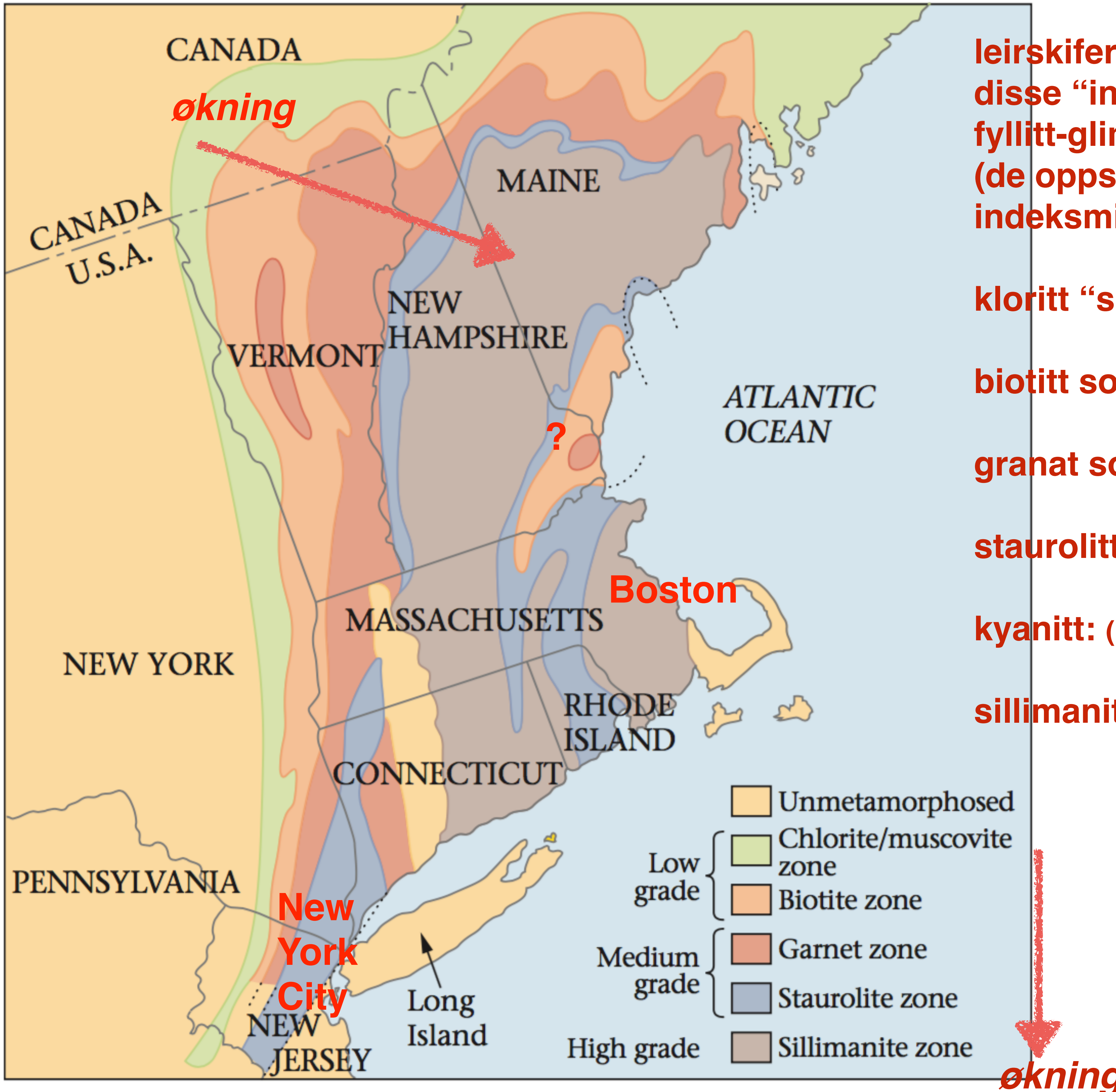



**FIGURE 8.21** Metamorphic zones as portrayed on a map of New England (U.S.A.). Isograds, defined by the first appearance of an index mineral, separate the zones.

leirskifer er rik på aluminium (Al).
disse "indeks" mineraler forekommer i fyllitt-glimmerskifer-gneis
(de oppstår ikke i ba. med lite Al)
indeksmineralene gir navn til sonene.

kloritt "sone": område med høy nok temp. til dannelse av kloritt

biotitt sone: område med høy nok temp. til dannelse av metamorf biotitt

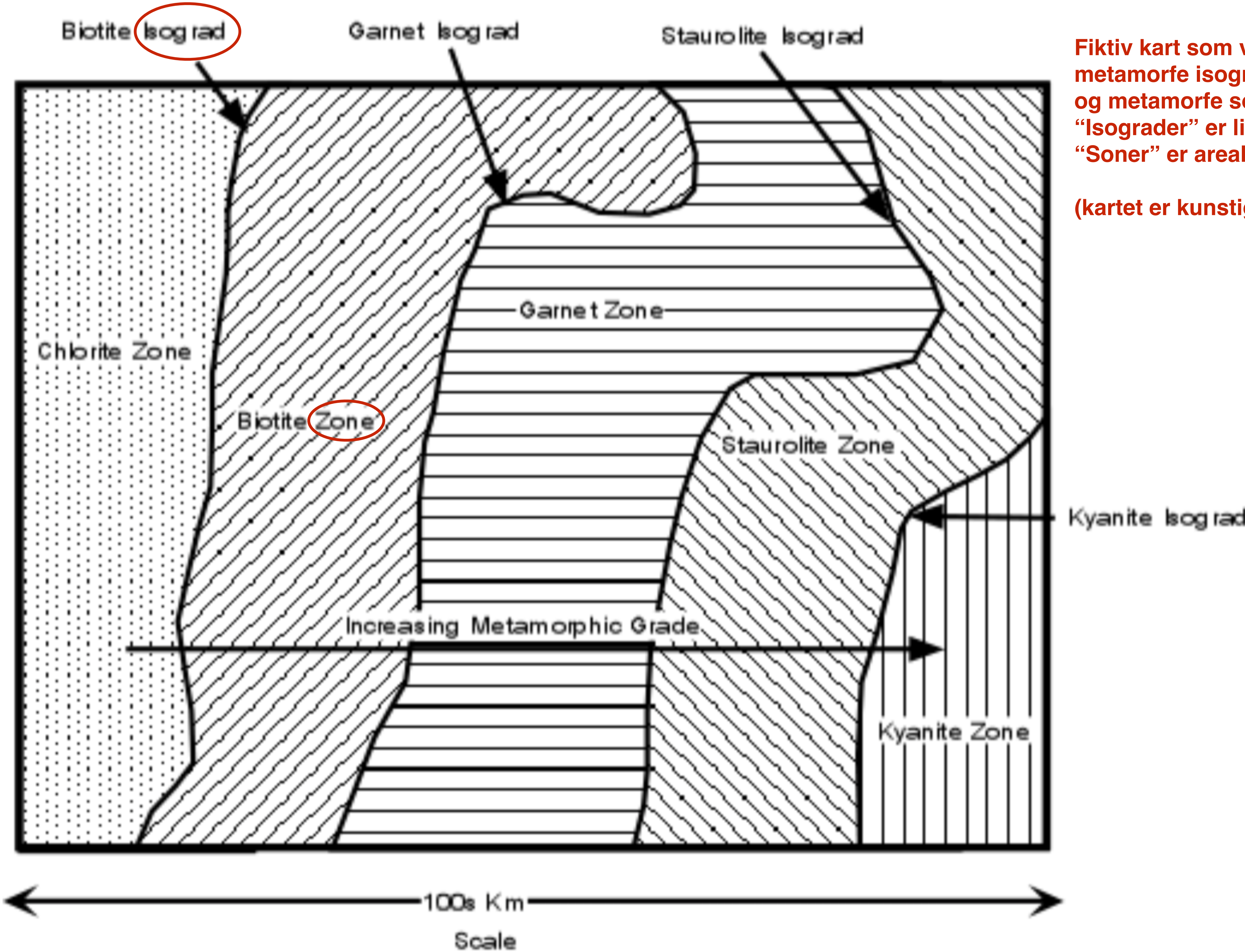
granat sone: (samme prinsipp)

staurolitt:

kyanitt: (ikke forekommer her fordi trykk var for lav)

sillimanitt:

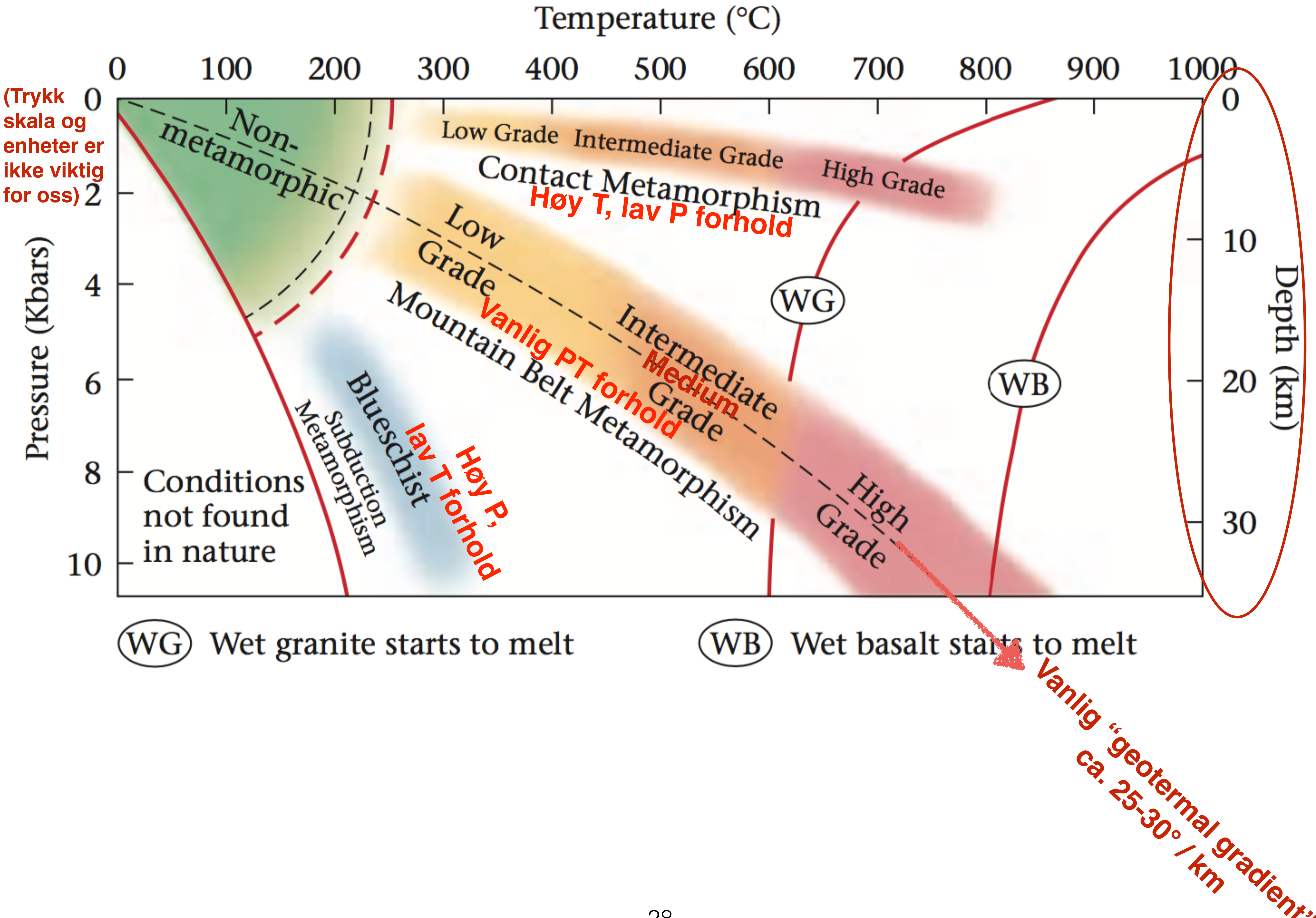
"isograd": nedre temperaturgrense for den angitte "sonen".

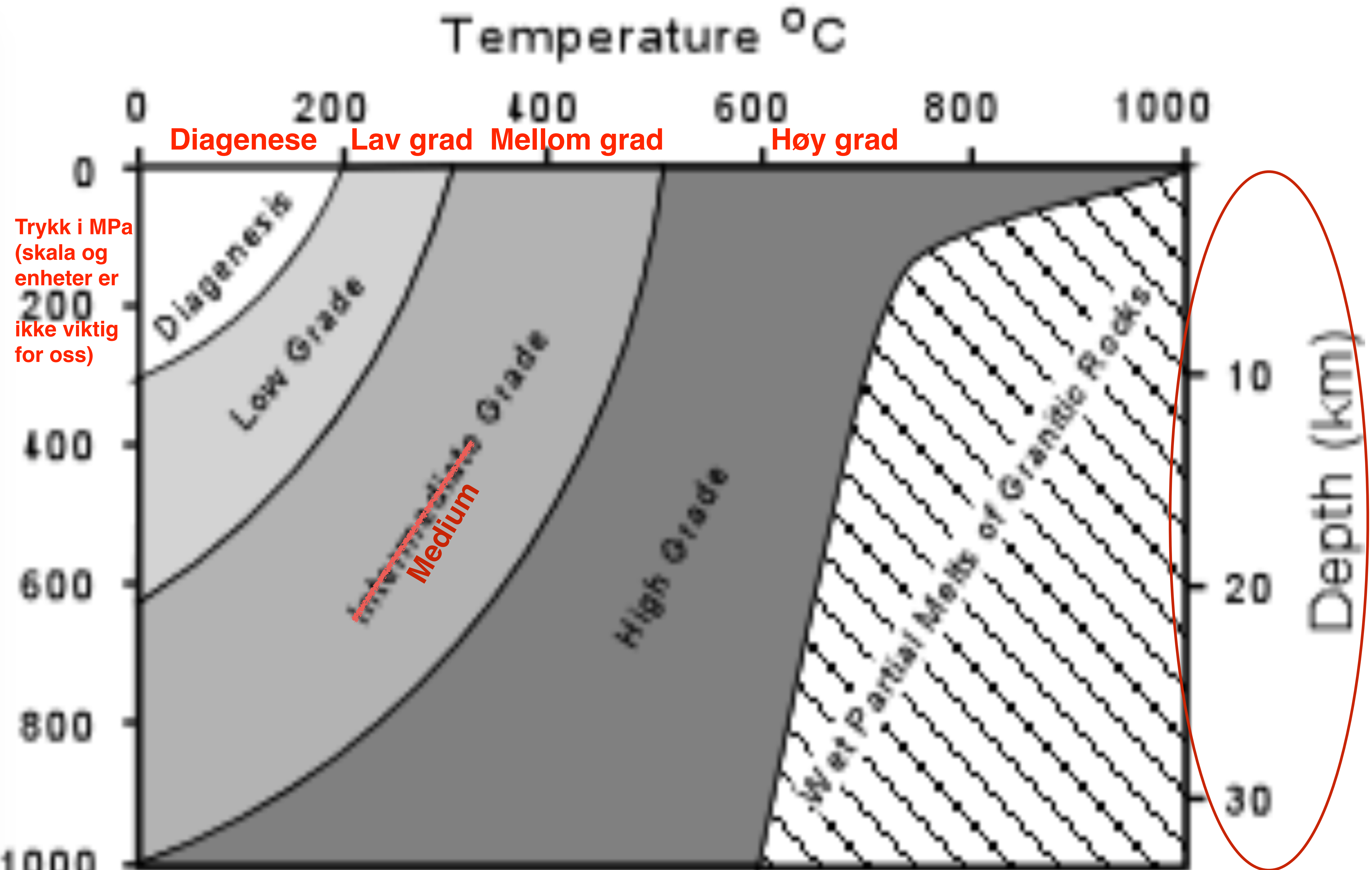



**Fiktiv kart som viser metamorfe isograder og metamorfe soner. "Isograder" er linjer. "Soner" er arealer.**

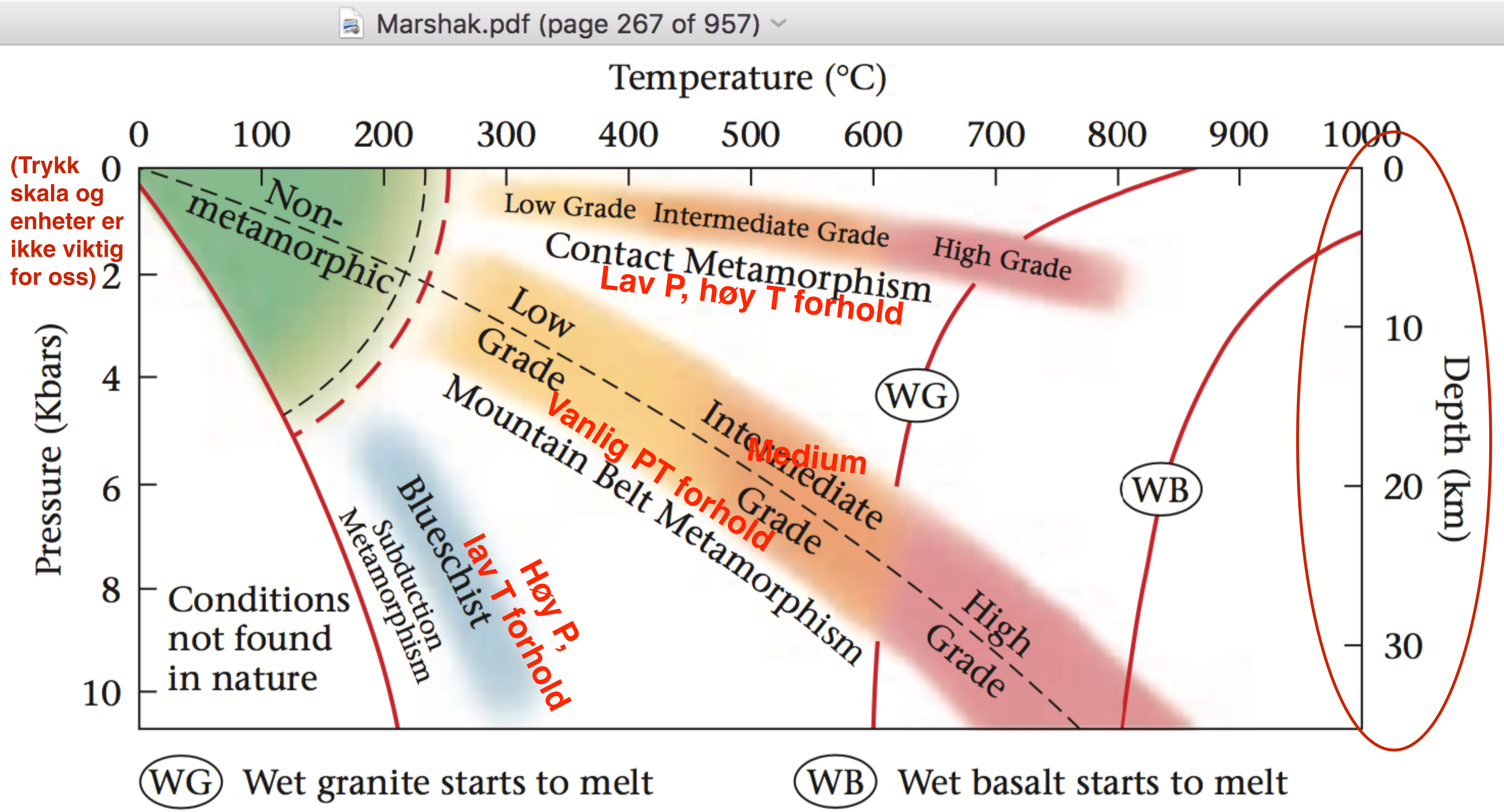
**(kartet er kunstig)**

# Metamorfe *GRADER*






Geologer sier “Medium grade” (ikke “Intermediate grade”!)




**Det er ikke enighet mellom Marshak og Nelson om temperatur skala.**
**(Uenigheter er vanlig i geologi.)**

**For eksempel: grense mellom**
**lav-grad/mellom-grad er 400° ved Marshak, bare 300° ved Nelson**

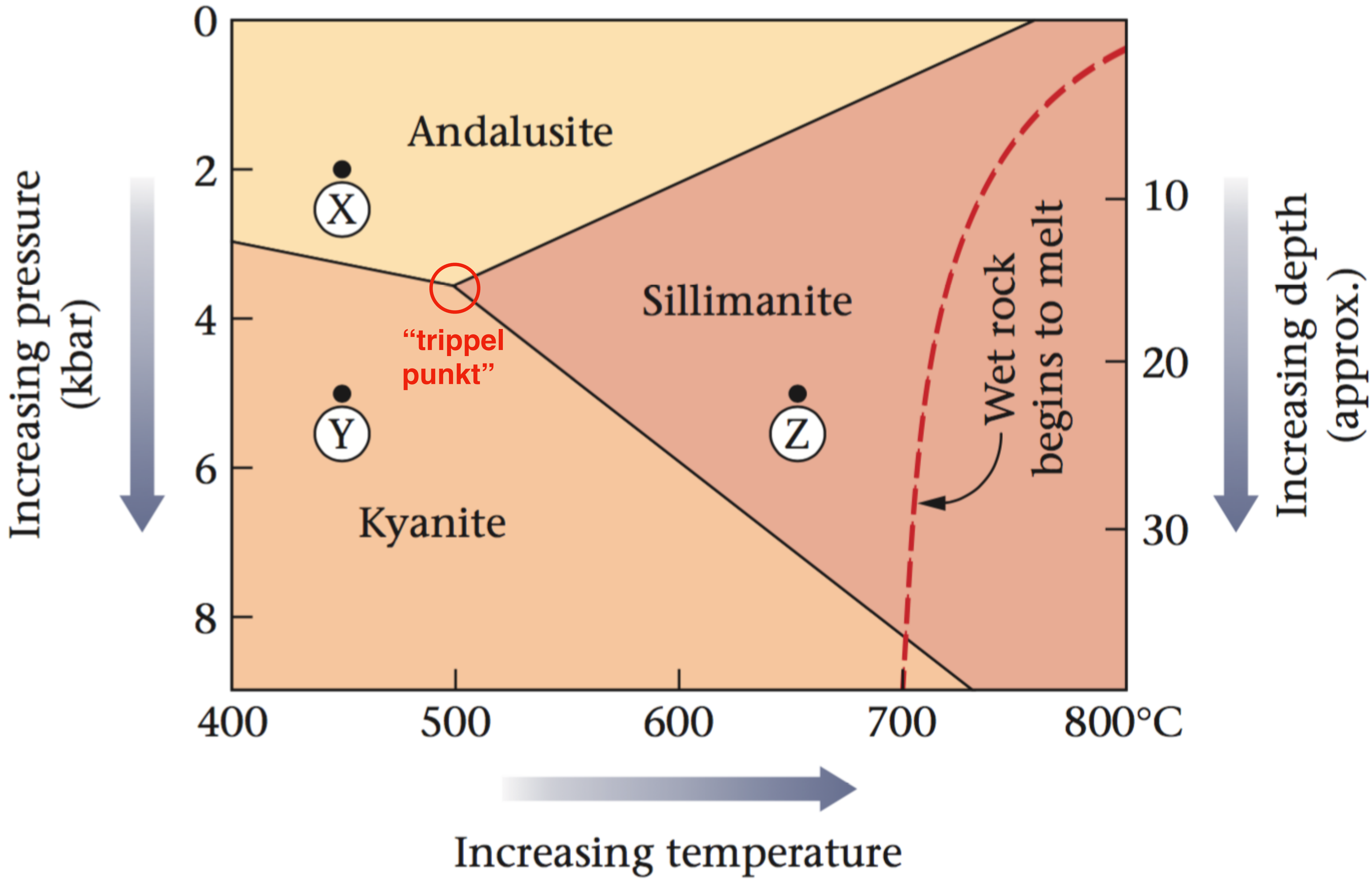



**FIGURE 8.3** The stability fields for three metamorphic minerals (kyanite, andalusite, and sillimanite) that are polymorphs of $Al_2SiO_5$ (aluminum silicate) can be depicted on a phase diagram. At a pressure of 2 kbar and a temperature of 450°C (point X), andalusite is stable. At 5 kbar and 450°C (point Y), kyanite is stable. At 5 kbar and 650°C (point Z), sillimanite is stable.

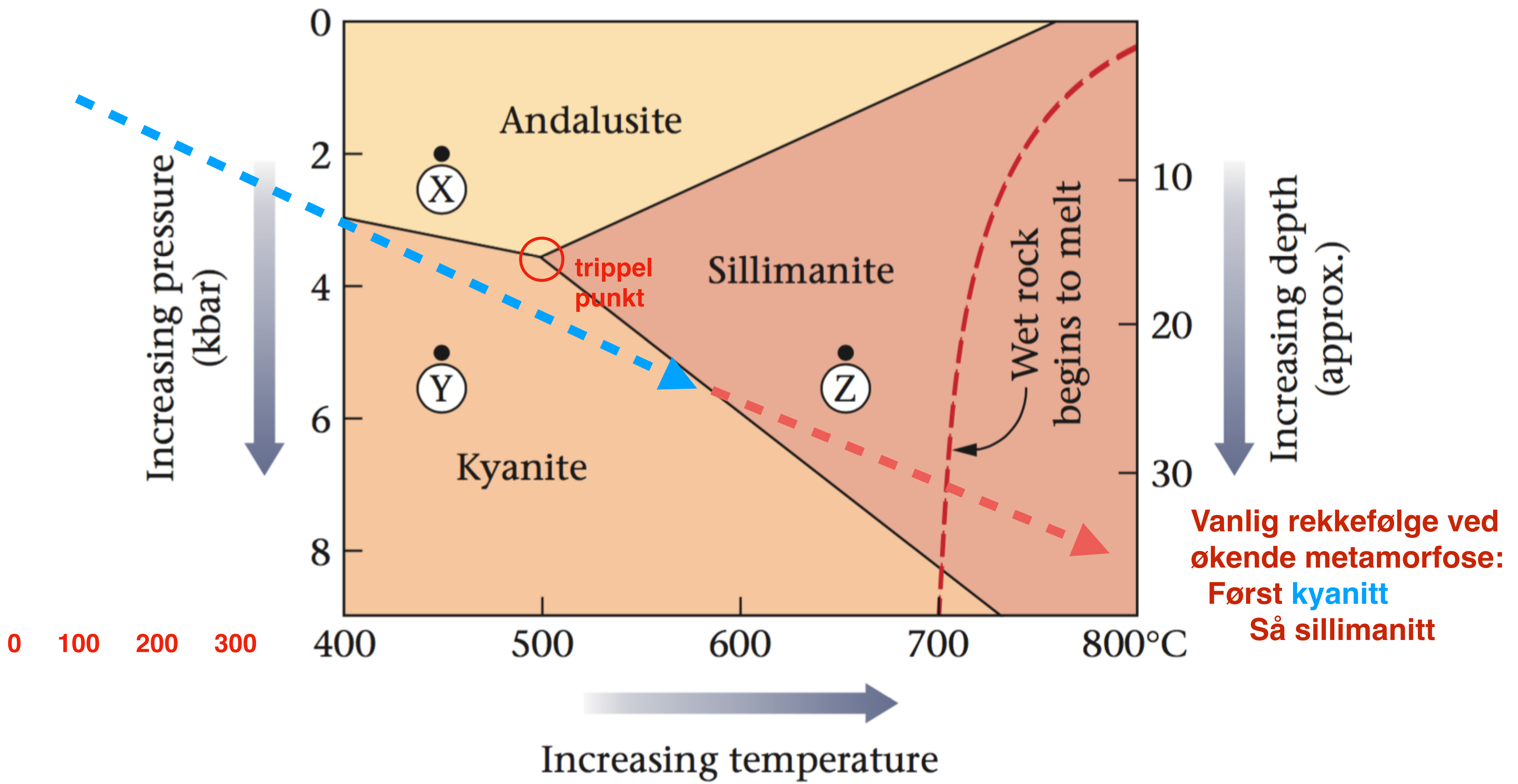
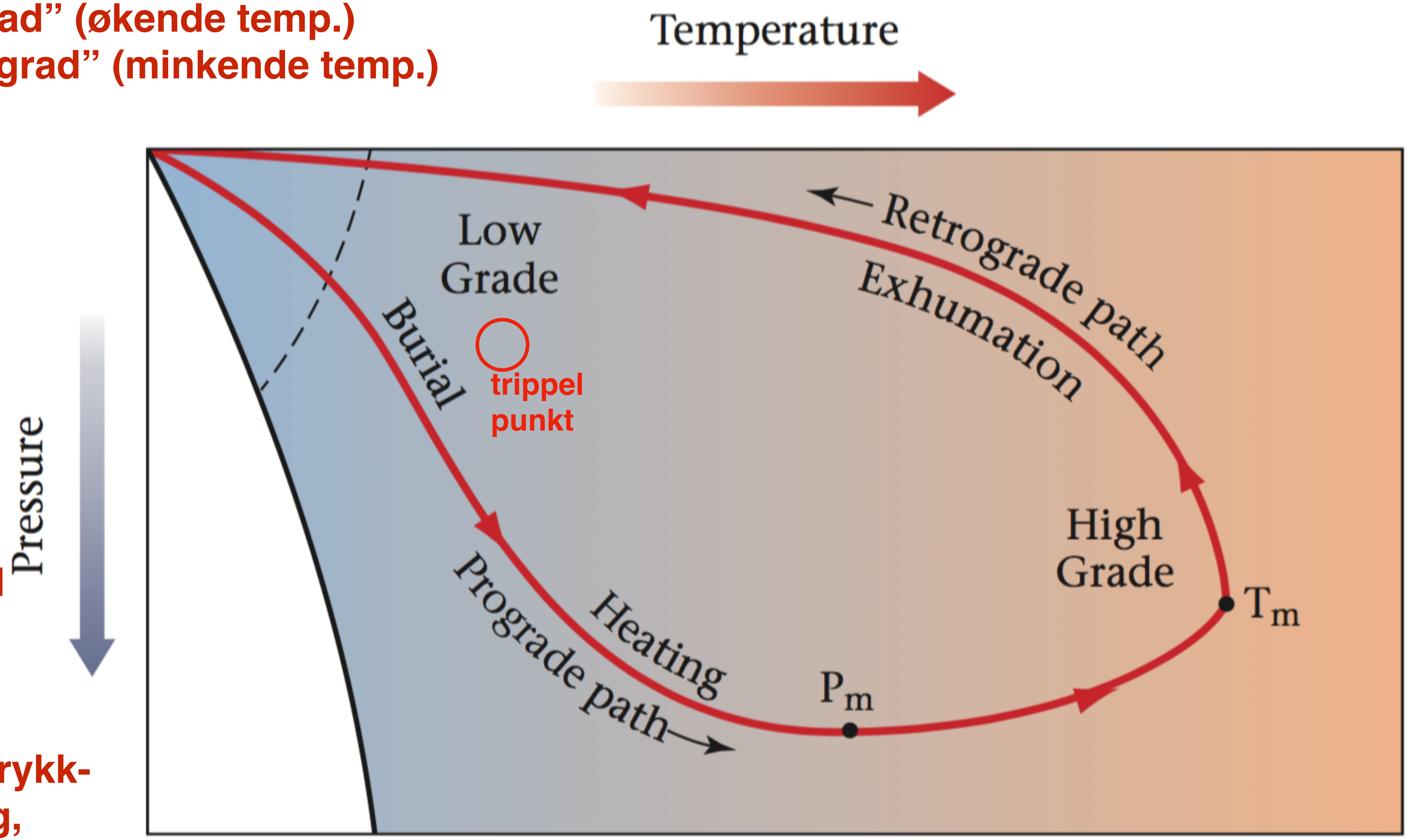



**FIGURE 8.3** The stability fields for three metamorphic minerals (kyanite, andalusite, and sillimanite) that are polymorphs of $Al_2SiO_5$ (aluminum silicate) can be depicted on a phase diagram. At a pressure of 2 kbar and a temperature of 450°C (point X), andalusite is stable. At 5 kbar and 450°C (point Y), kyanite is stable. At 5 kbar and 650°C (point Z), sillimanite is stable.

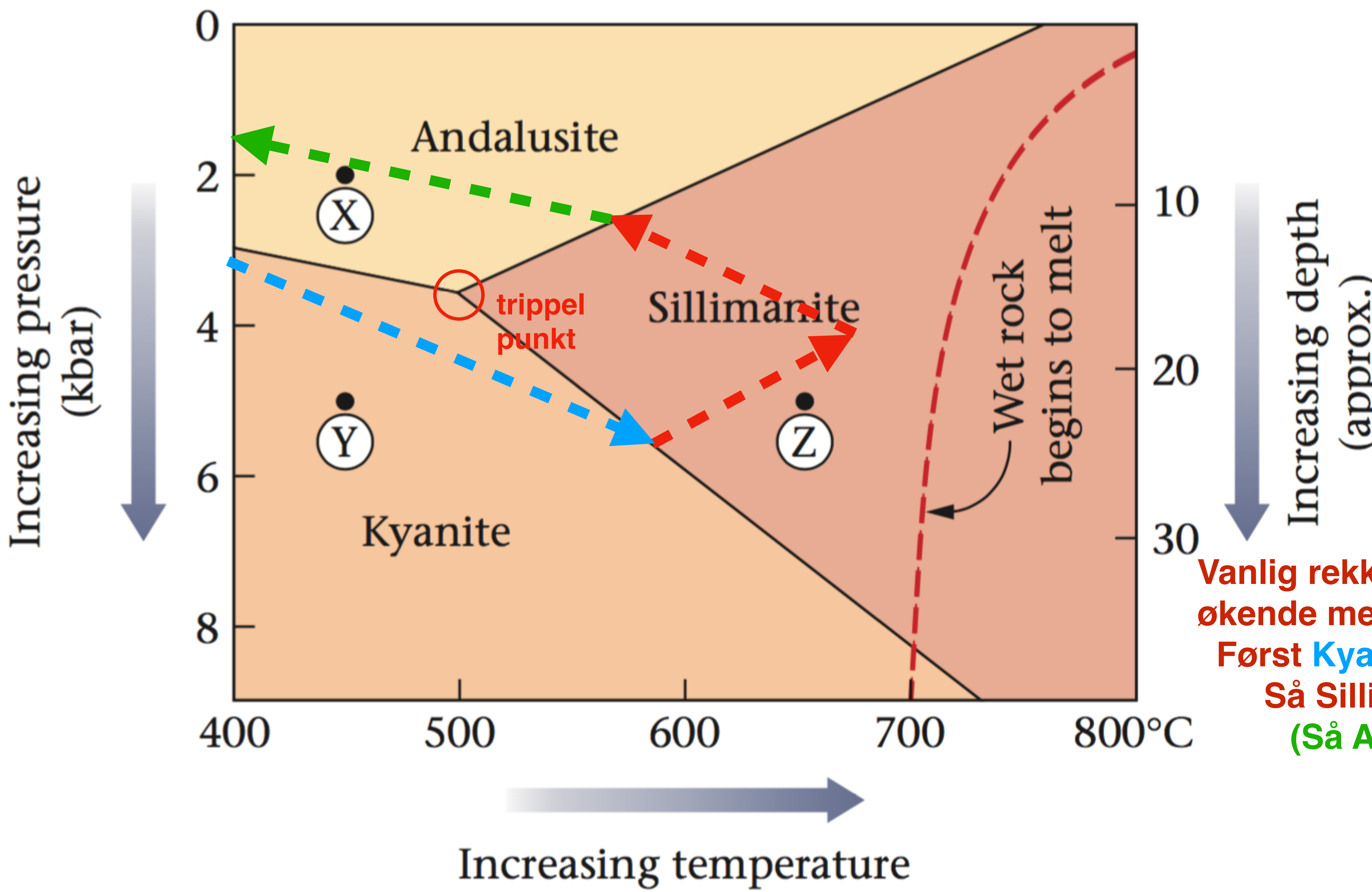
**"Prograd" (økende temp.)**
**"Retrograd" (minkende temp.)**




**Bergart starter ved overflaten og blir presset ned.**

**Bergarter merker trykk-endring øyblikkelig, mens temperaturendring tar tusener av år å merkes.**

**FIGURE 8.20** The metamorphic history of a rock can be portrayed on a graph showing variations in temperature and pressure. This graph shows one of many possible paths. As a rock experiences increased heating and pressure, it undergoes prograde metamorphism. As the temperature and pressure decrease, the rock undergoes retrograde metamorphism, if water can be added back. $P_m$ is the peak pressure, and $T_m$ is the peak temperature. In this example, the rock was buried so quickly that it reached its peak pressure before it reached its peak temperature.




Vanlig rekkefølge ved økende metamorfose:
Først Kyanitt
Så Sillimanitt.
(Så Andalusitt)

**FIGURE 8.3** The stability fields for three metamorphic minerals (kyanite, andalusite, and sillimanite) that are polymorphs of $Al_2SiO_5$ (aluminum silicate) can be depicted on a phase diagram. At a pressure of 2 kbar and a temperature of 450°C (point X), andalusite is stable. At 5 kbar and 450°C (point Y), kyanite is stable. At 5 kbar and 650°C (point Z), sillimanite is stable.