Metamorfismo

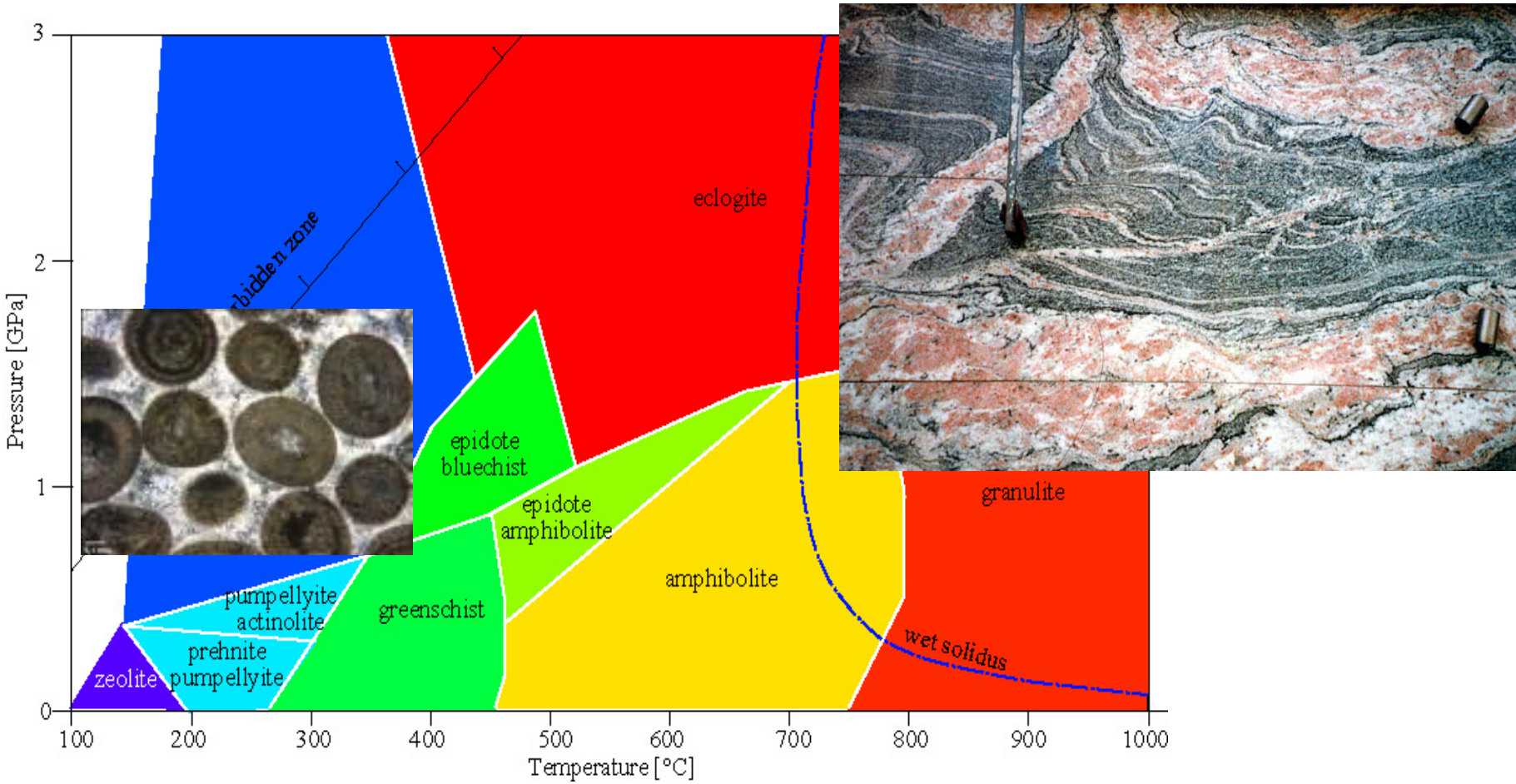
Definição (IUGS-SCMR) :

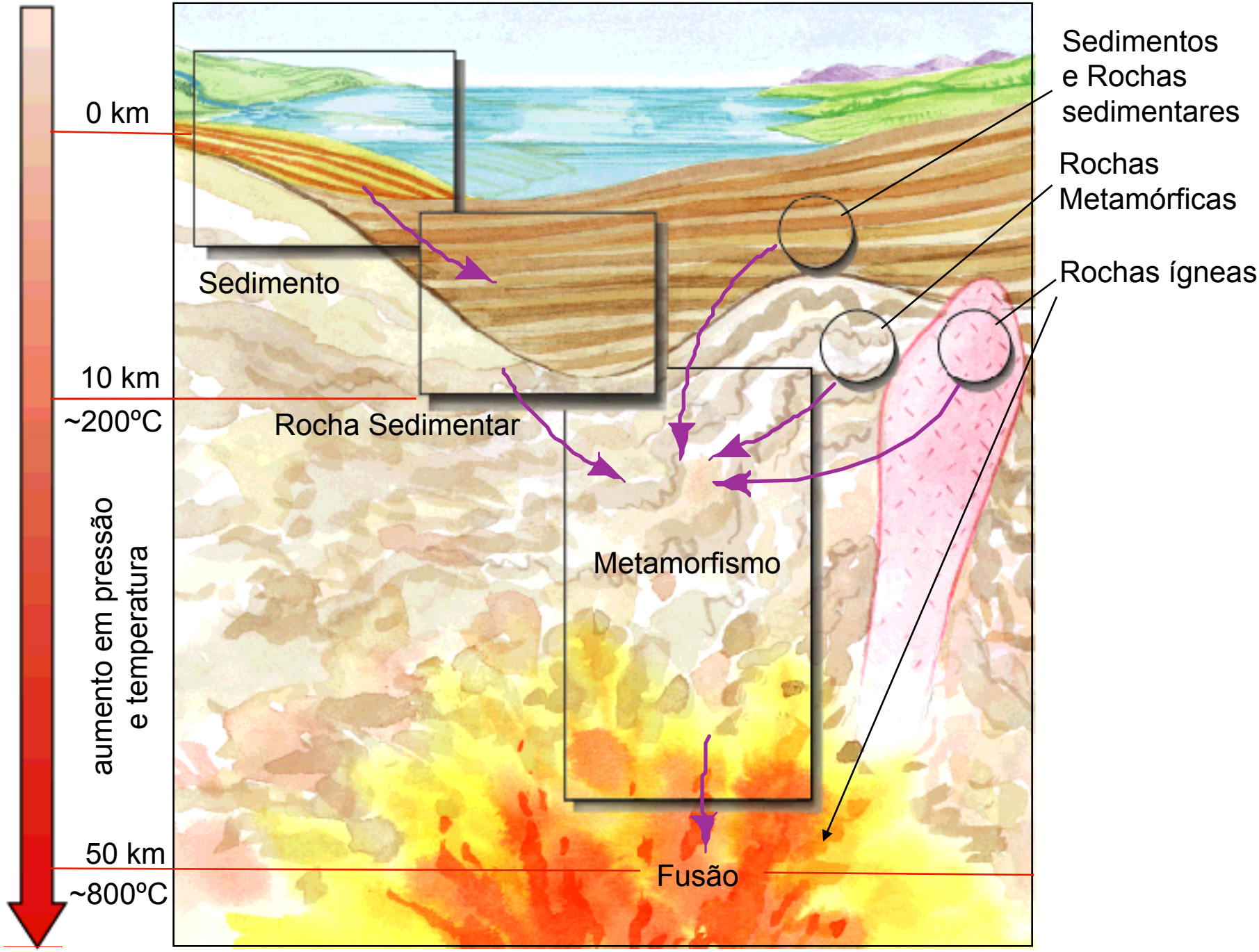
"Metamorfismo é um processo que ocorre em estado subsolidus (reações em estado sólido) e que gera mudanças na mineralogia e/ou textura e frequentemente leva a mudanças na composição de uma rocha. Essas mudanças se devem a condições físicas e/ou químicas que diferem daquelas encontradas na superfície dos planetas e nas zonas onde ocorre cimentação e diagênese abaixo dessa superfície. As condições metamórficas podem coexistir com a fusão parcial das rochas"

Os Limites do Metamorfismo

O limite de baixa Temperatura é a diagênese (100-150ºC para rochas mais instáveis).

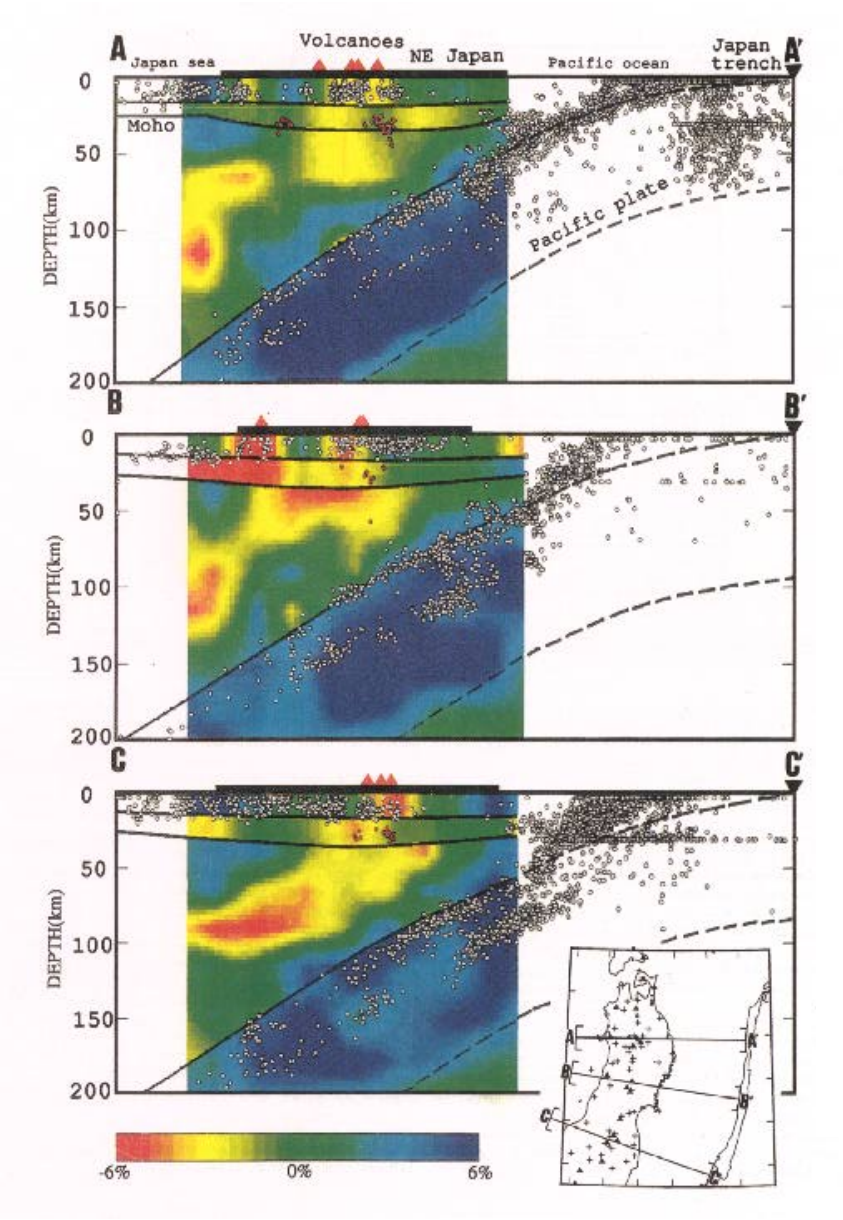
O Limite de alta Temperatura é a fusão (>650ºC para as rochas hidratadas, podendo chegar a >1400ºC no caso das rochas de ultra-high-T). Migmatitos são rochas híbridas, formadas por fusão parcial, contém neossoma e paleossoma.



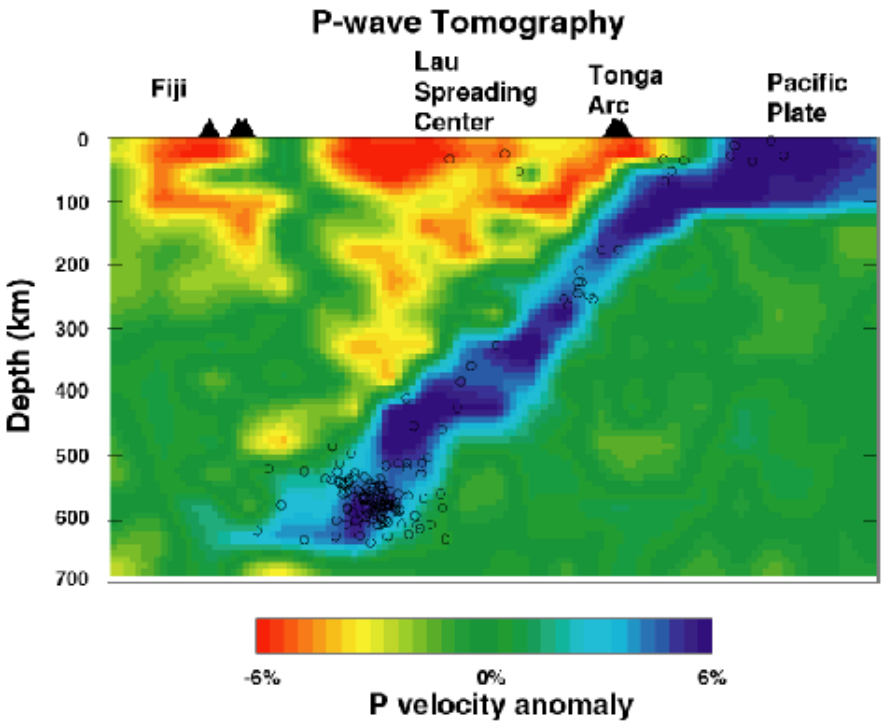

0 km
10 km
~200ºC
50 km
~800ºC
aumento em pressão
e temperatura
Sedimento
Rocha Sedimentar
Metamorfismo
Fusão
Sedimentos
e Rochas
sedimentares
Rochas
Metamórficas
Rochas ígneas

E como se dá o aumento de Temperatura e Pressão?

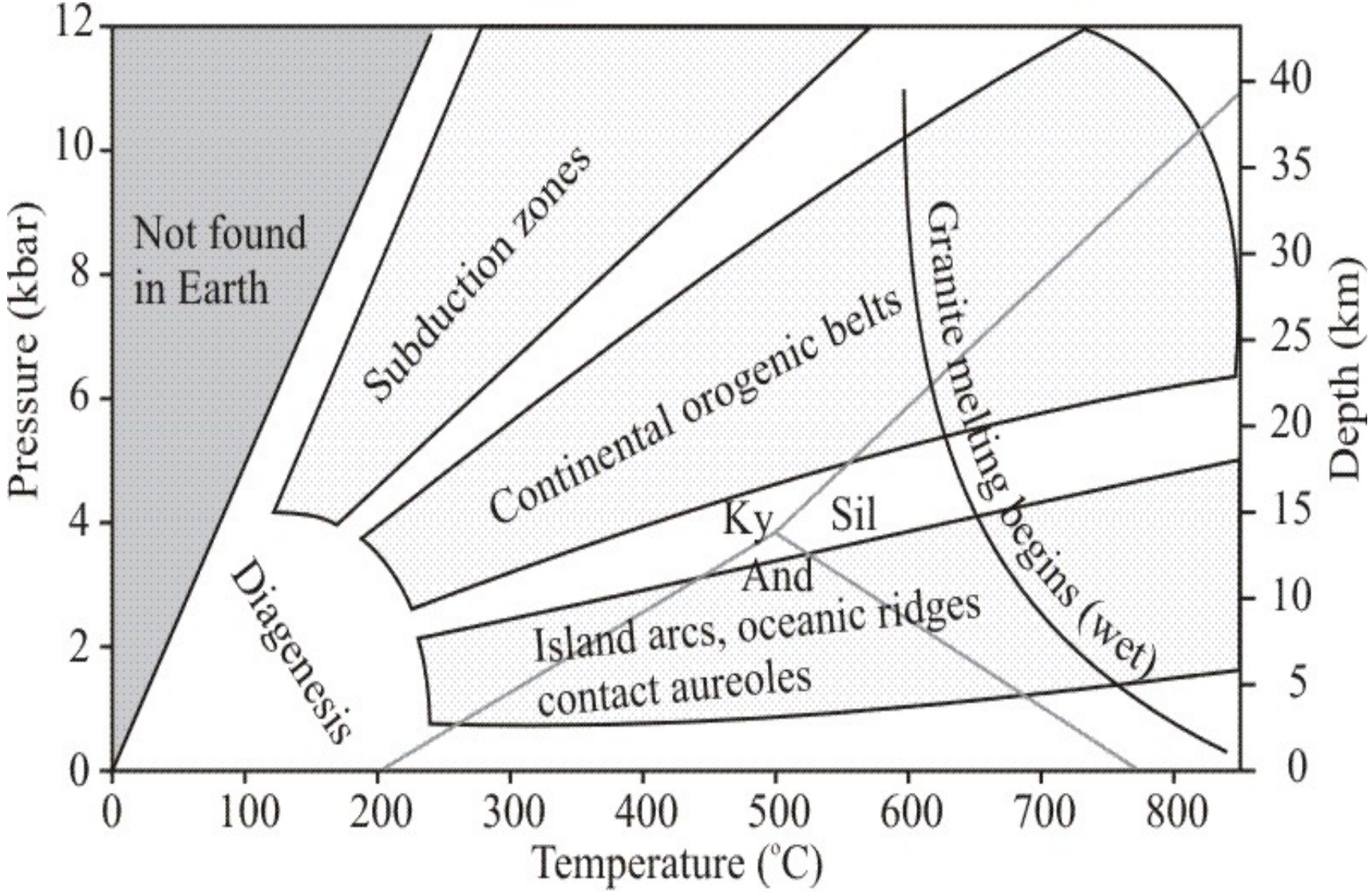
…via Tectônica de Placas,



em azul as anomalias de alta velocidade de ondas-P



from: http://www.pmel.noaa.gov/vents/coax/coax.html


Not found
in Earth
Subduction zones
Continental orogenic belts
Granite melting begins (wet)
Ky
Sil
And
Island arcs, oceanic ridges
contact aureoles
Diagenesis
Pressure (kbar)
Depth (km)
Temperature (°C)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600
700
800

Agentes de Metamorfismo: Pressão

Gradientes de Pressão-Temperatura "normais" são perturbados de diferentes formas, sendo as mais comuns:

- Regiões com alta T/P em áreas com atividade plutônica ou em áreas de rifting
- Regiões de baixa T/P em zonas de subducção

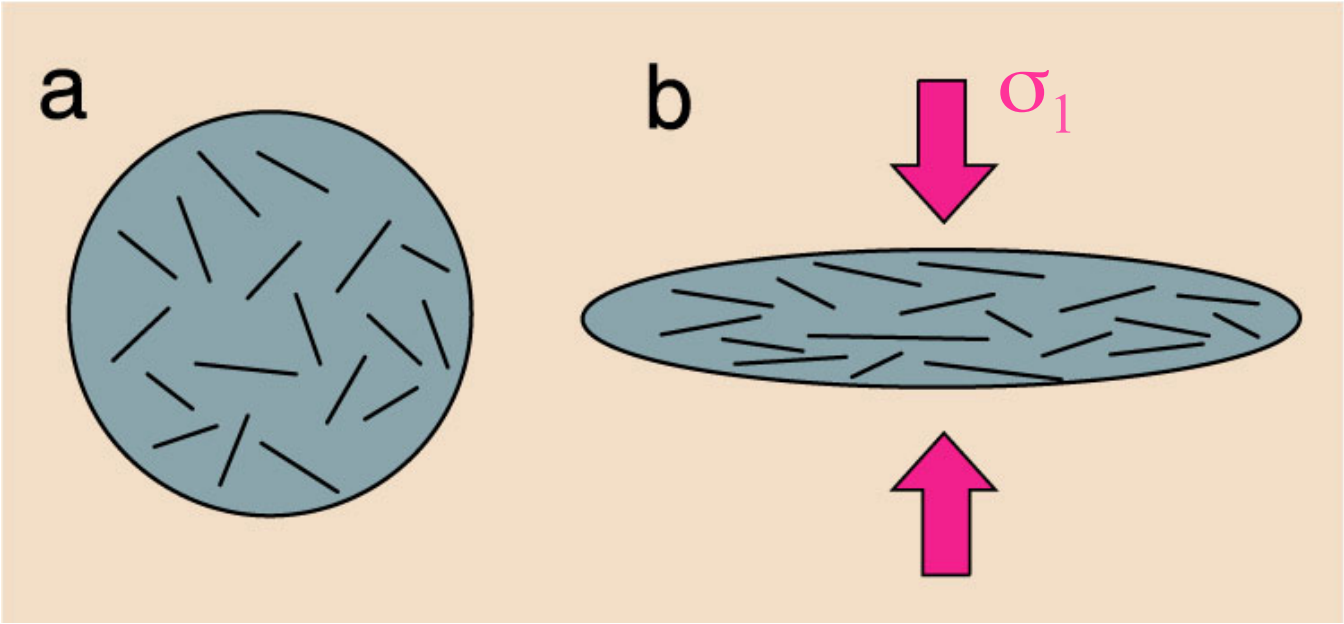
Pressão litostática = resulta da carga de rochas sobrepostas

$(P = \Delta d.g.h)$

Esforço deviatórico = pressões diferentes em diferentes direções:

σ_1, σ_2 e σ_3

- Foliação permite estimar a orientação de σ_1



- $\sigma_1 > \sigma_2 = \sigma_3 \rightarrow$ foliação, sem lineação
- $\sigma_1 = \sigma_2 > \sigma_3 \rightarrow$ lineação, sem foliação
- $\sigma_1 > \sigma_2 > \sigma_3 \rightarrow$ foliação E lineação

Figure 21.3. Flattening of a ductile homogeneous sphere (a) containing randomly oriented flat disks or flakes. In (b), the matrix flows with progressive flattening, and the flakes are rotated toward parallelism normal to the predominant stress. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Cisalhamento: movimento ao longo de um plano oblíquo a σ_1

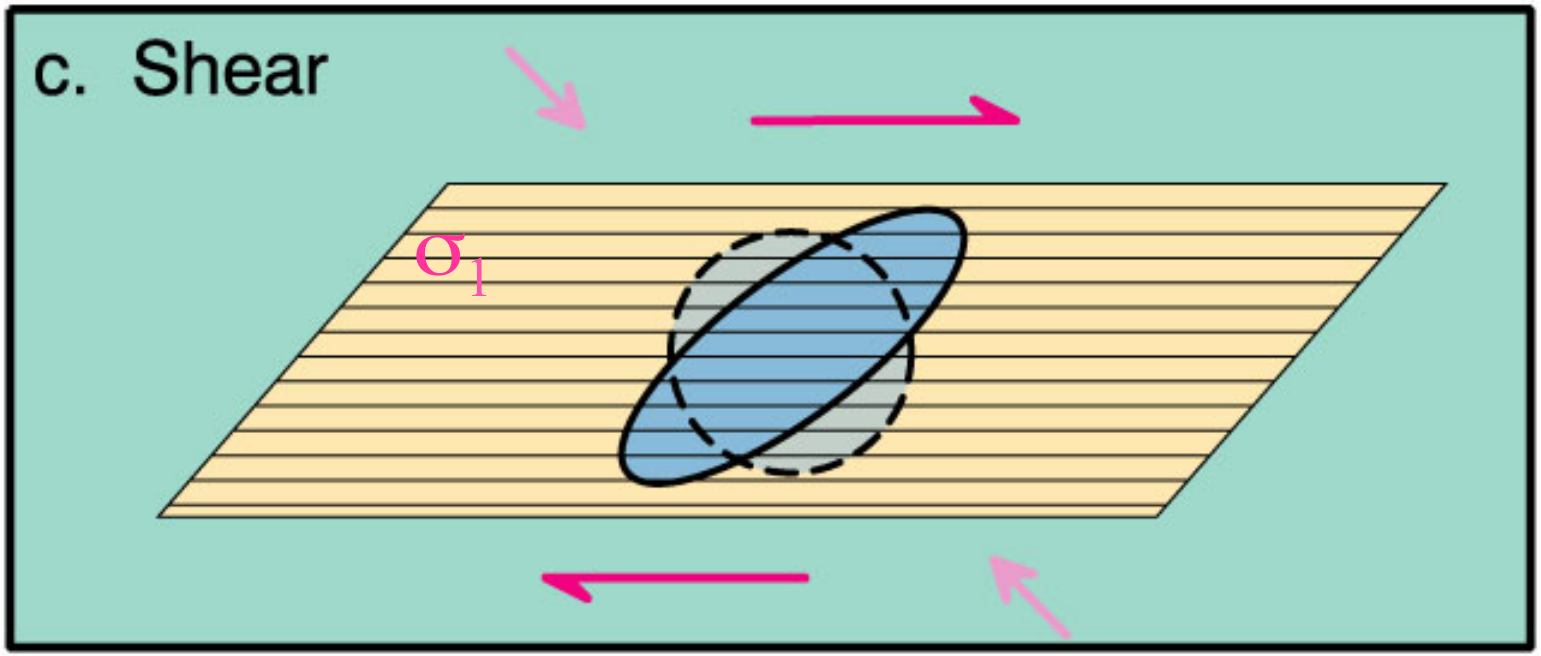


Figure 21.2. The three main types of deviatoric stress with an example of possible resulting structures. b. Shear, causing slip along parallel planes and rotation. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Texturas metamórficas indicativas de ação de esforço deviatórico

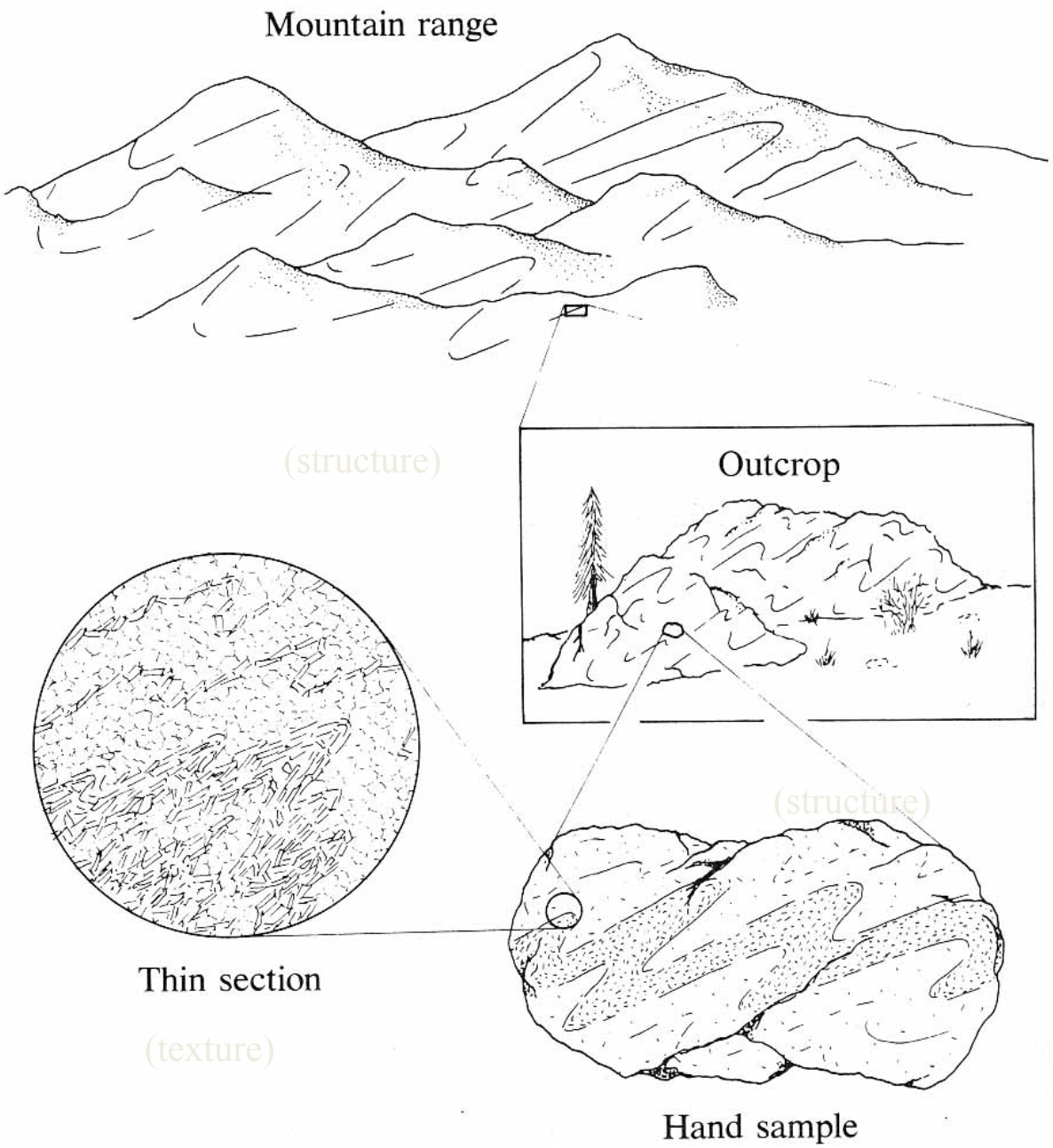


Diagram showing that structural and fabric elements are generally consistent in style and orientation at all scales. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

Texturas Metamórficas: Metamorfismo Dinâmico

Deformação, Recuperação, Recristalização

1) Fluxo Cataclástico

- Fragmentação mecânica, rotação e deslizamemto entre grãos.

2) Fluxo Milonítico

- Recristalização, deslizamento intracristalino, por vezes associado a fusão parcial (zonas de alto grau metamórfico

Zonas com alta intensidade deformação (Zonas de cisalhamento)

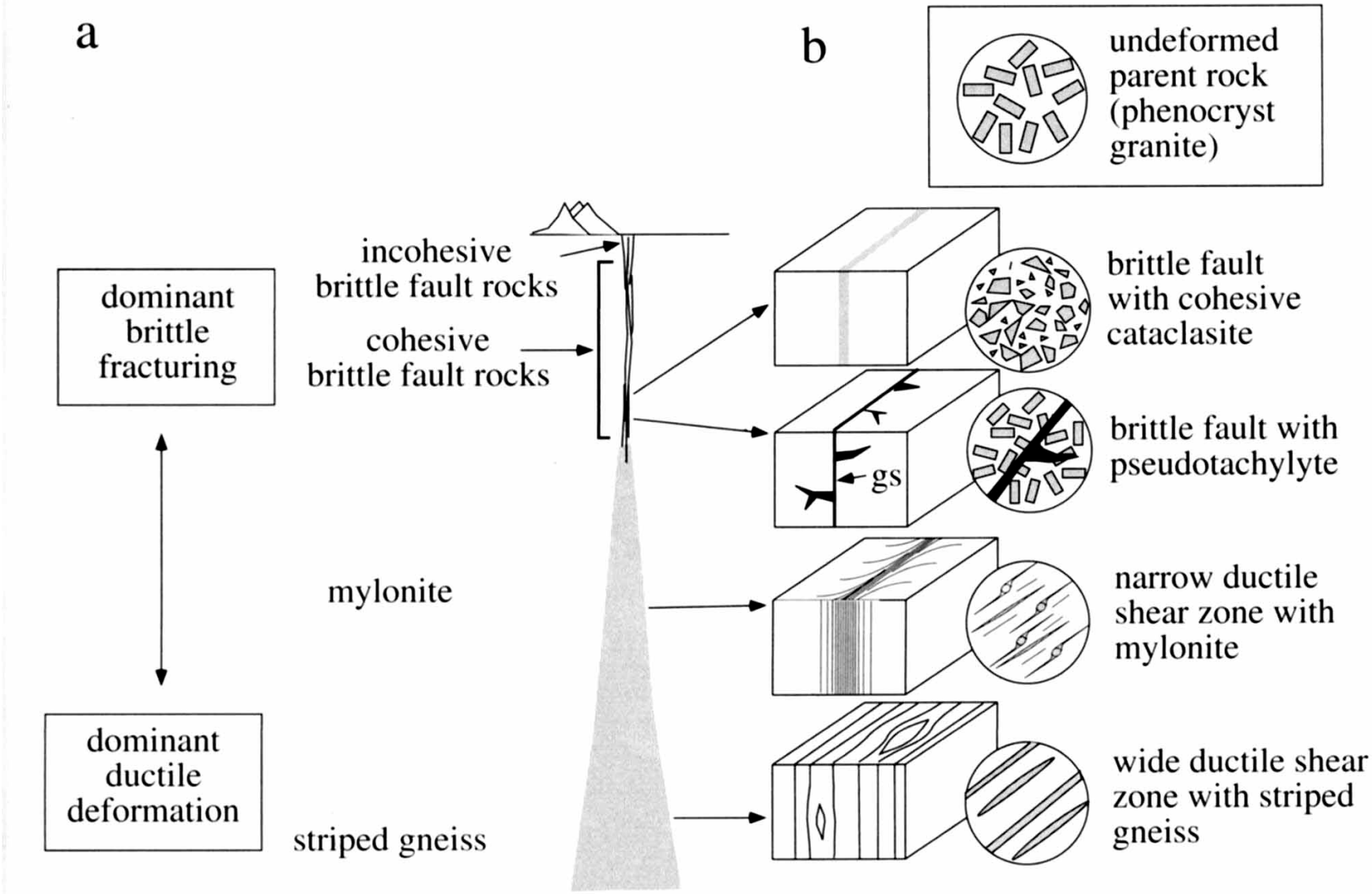
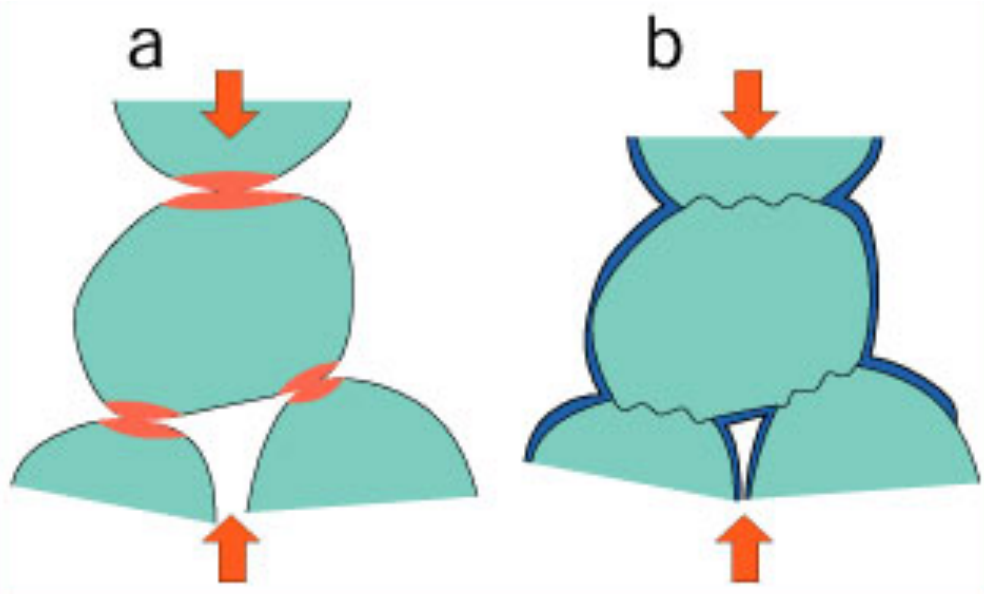


Figure 22.2. Schematic cross section through a shear zone, showing the vertical distribution of fault-related rock types, ranging from non-cohesive gouge and breccia near the surface through progressively more cohesive and foliated rocks. Note that the width of the shear zone increases with depth as the shear is distributed over a larger area and becomes more ductile. Circles on the right represent microscopic views or textures. From Passchier and Trouw (1996) *Microtectonics*. Springer-Verlag. Berlin.

Mecanismos de Deformação

1. Dissolução por pressão



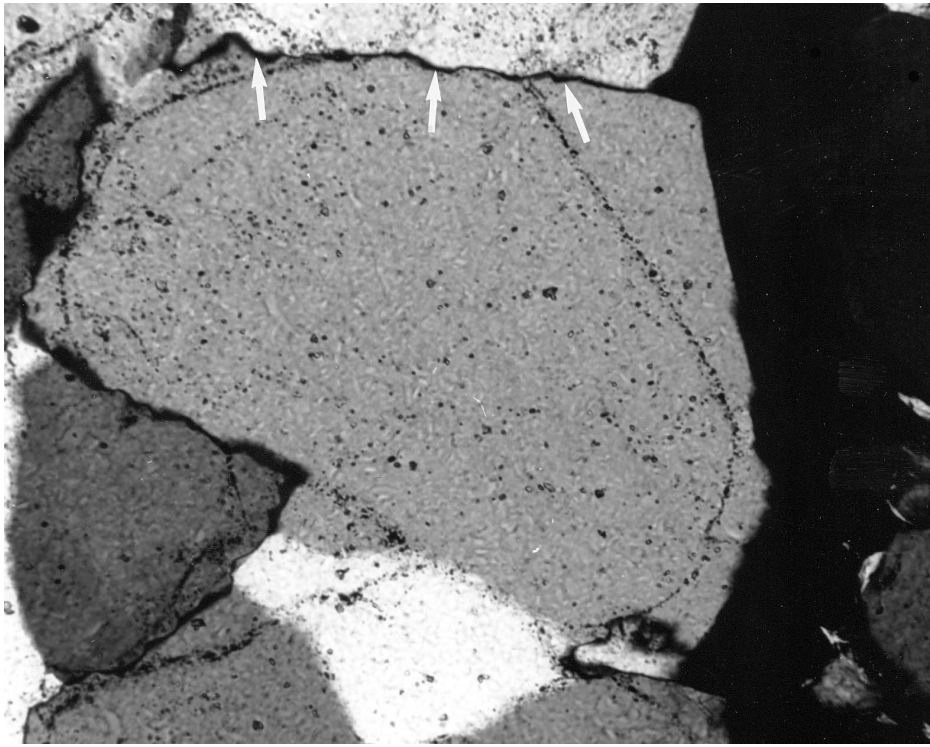


Figure 23.2 a. Highest strain in areas near grain contacts (hatch pattern). b. High-strain areas dissolve and material precipitates in adjacent low-strain areas (shaded). The process is accompanied by vertical shortening. c. Pressure solution of a quartz crystal in a deformed quartzite (σ_1 is vertical). Pressure solution results in a serrated solution surface in high-strain areas (small arrows) and precipitation in low-strain areas (large arrow). ~ 0.5 mm across. The faint line within the grain is a hematite stain along the original clast surface. After Hibbard (1995) *Petrography to Petrogenesis*. Prentice Hall.

Mecanismos de Deformação

2. Deformação plástica intracristalina

- Não há perda de coesão
- Processos:
  - Migração de defeitos da rede cristalina
  - Planos de deslizamento preferenciais
  - Geminação por deformação

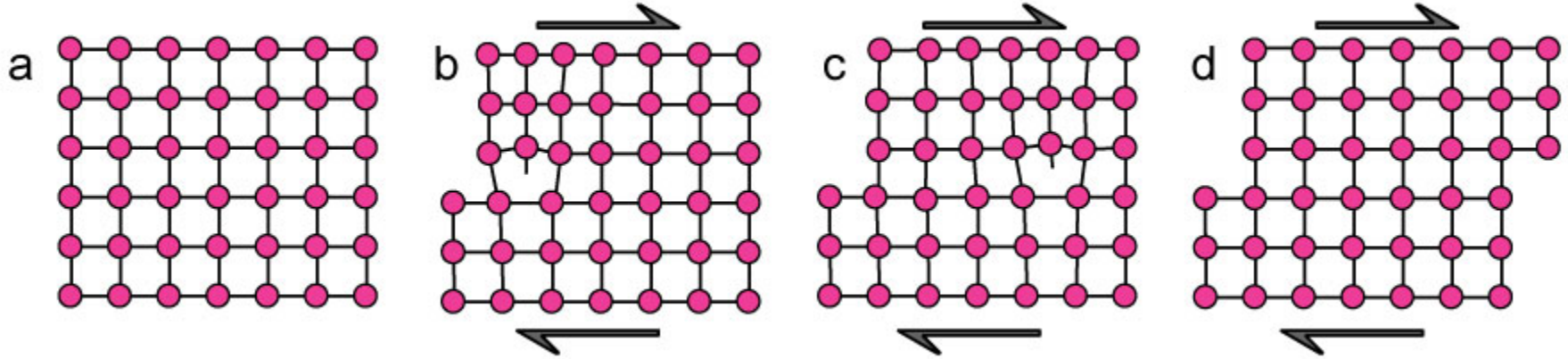
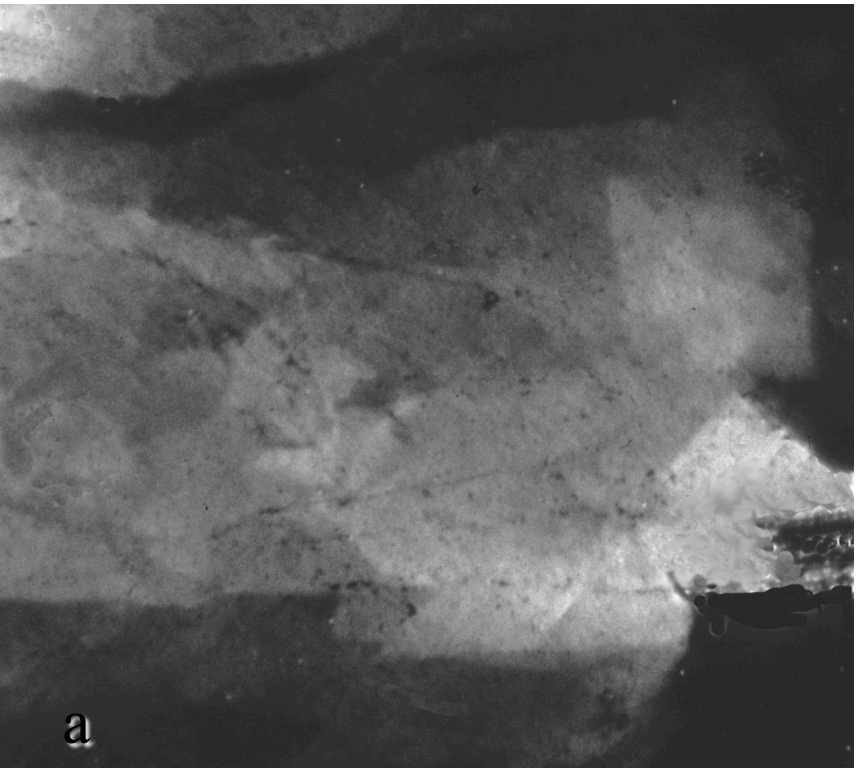


Figure 23.3. Plastic deformation of a crystal lattice (experiencing dextral shear) by the migration of an edge dislocation (as viewed down the axis of the dislocation).



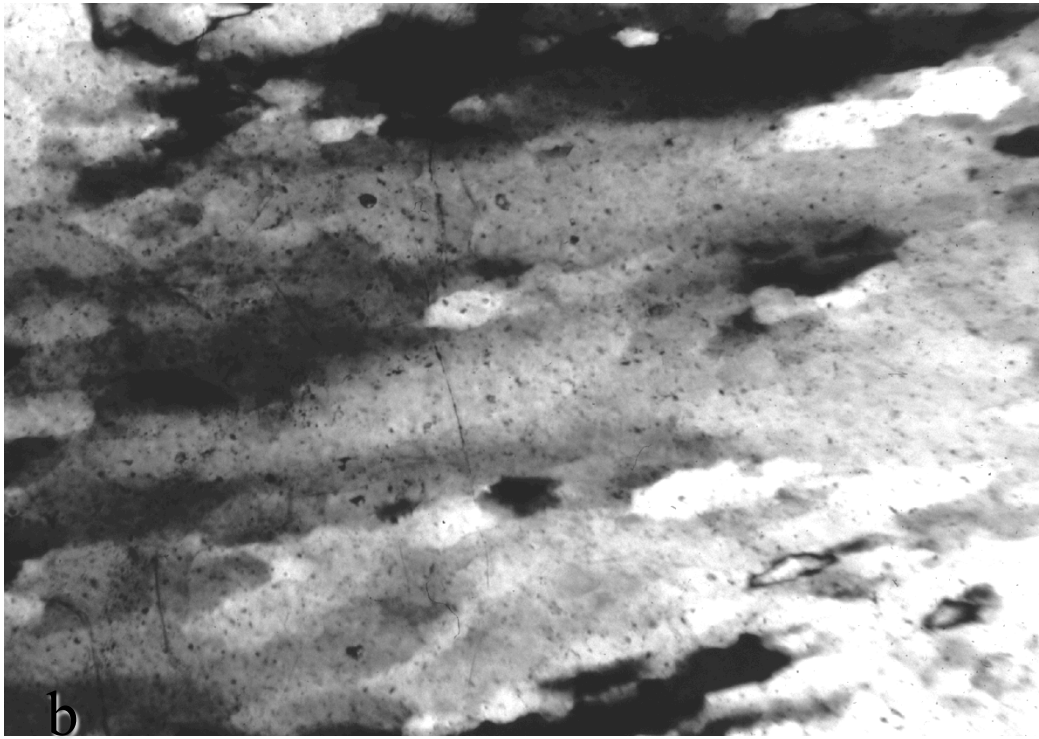


Figure 23.4 a. Undulose extinction and (b) elongate subgrains in quartz due to dislocation formation and migration Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Mecanismos de Deformação

3. Recuperação

- Perda da energia acumulada durante o processo de deformação e poligonização dos grãos.

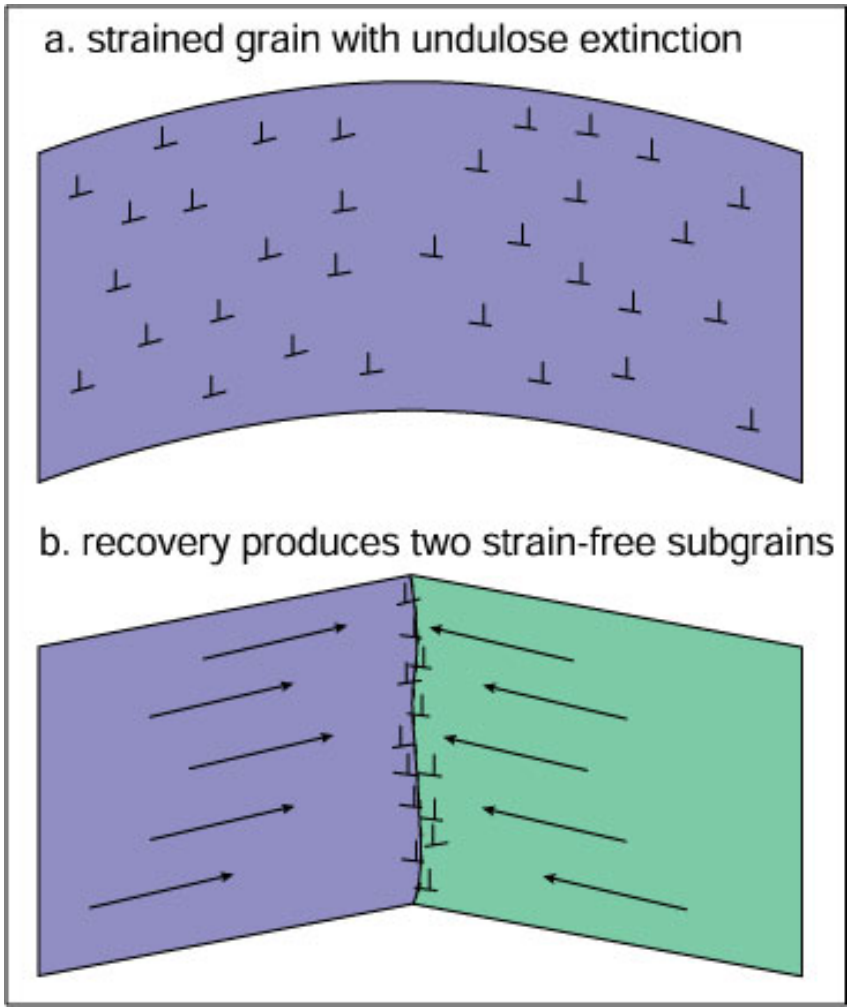


Figure 23.5. Illustration of a recovery process in which dislocations migrate to form a subgrain boundary. Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

4. Recristalização

- Migração do limite do grão
- Rotação de subgrãos
- Difusão em estado sólido (creep), em alta-T

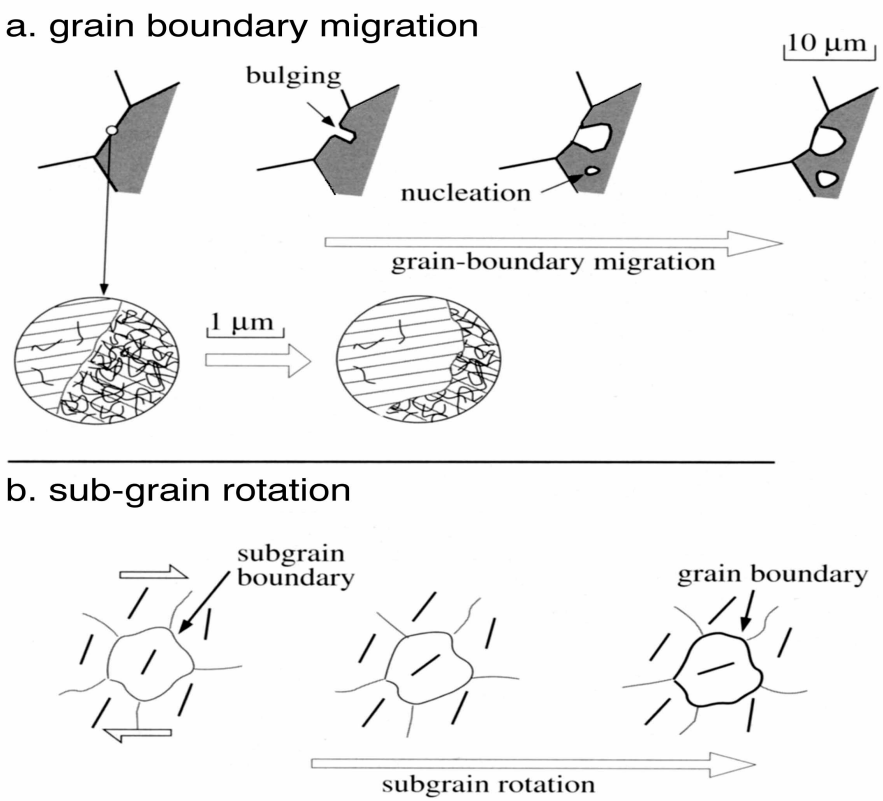
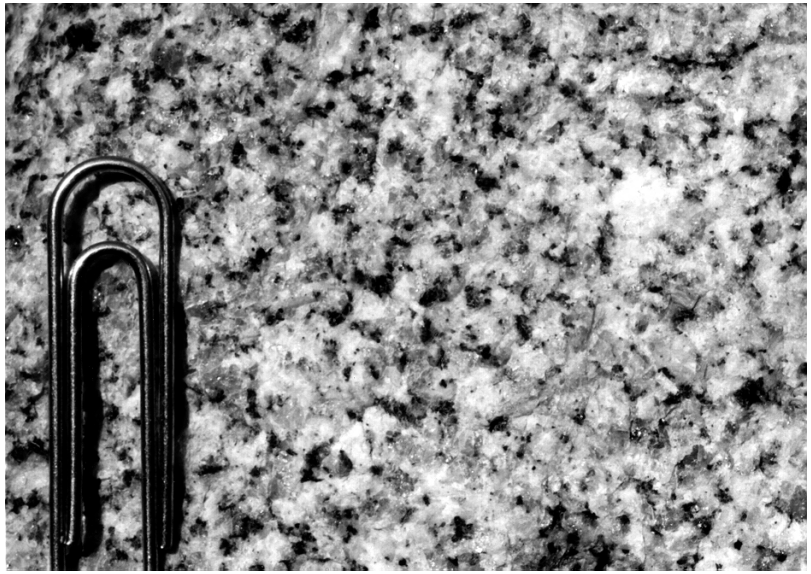
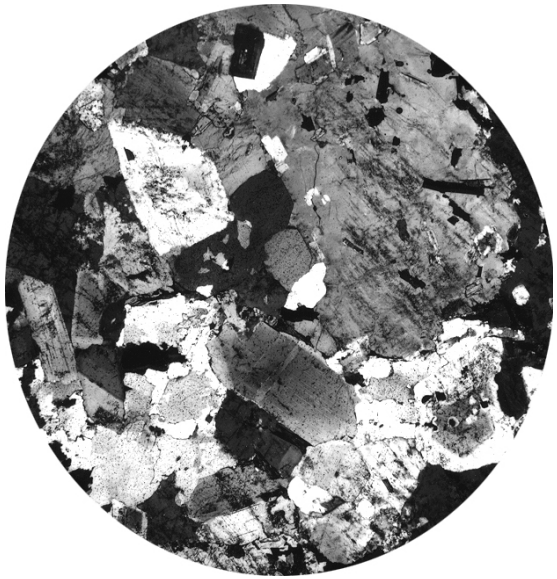


Figure 23.6. Recrystallization by (a) grain-boundary migration (including nucleation) and (b) subgrain rotation. From Passchier and Trouw (1996) *Microtectonics*. Springer-Verlag. Berlin.

Figure 23.7a. Recrystallized quartz with irregular (sutured) boundaries, formed by grain boundary migration. Width 0.2 mm. From Borradaile *et al*. (1982).

Texturas de rochas muito deformadas (high-strain rocks)

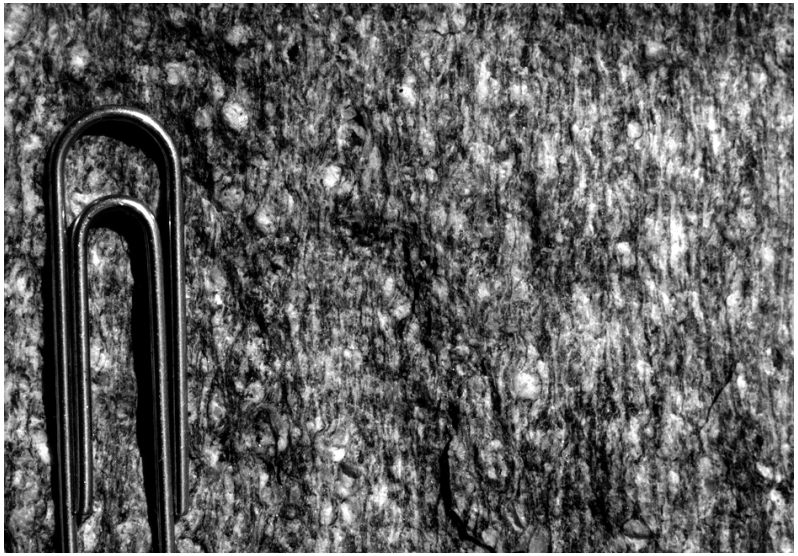




Granito
original

Metagranito
ou
Protomilonito
<50% matriz

- Texturas de rochas muito deformadas (milonitos)



Milonito
50-90% matriz

Ultramilonito
>90% fragmentos

Classificação de Rochas Miloníticas

(rochas fortemente afetadas por metamorfismo dinâmico)

Table 22-1. Classification of High-Strain Fault Zone Rocks

% fine matrix	Rocks without primary cohesion	Rocks with primary cohesion			
		Non-foliated	Foliated		Glass in matrix
	Fault breccia	Microbreccia	Protomylonite	Blastomylonite (if significantly recrystallized)	Pseudotachylite
50					
70			Mylonite		
90	Fault gouge	Cataclasite	Ultramylonite		

After Higgins (1971)

Tipos de foliação

a. Bandamento composicional
b. Orientação mineral de minerais tabulares (e.g. micas), formando uma xistosidade
c. Forma de grãos deformados
d. Variação de tamanho de grão
e. Orientação preferencial de micas em uma rocha dominantemente granoblástica
f. Orientação preferencial de agregados lenticulares de grãos
g. Orientação preferencial de fraturas
h. Combinações de a-g.

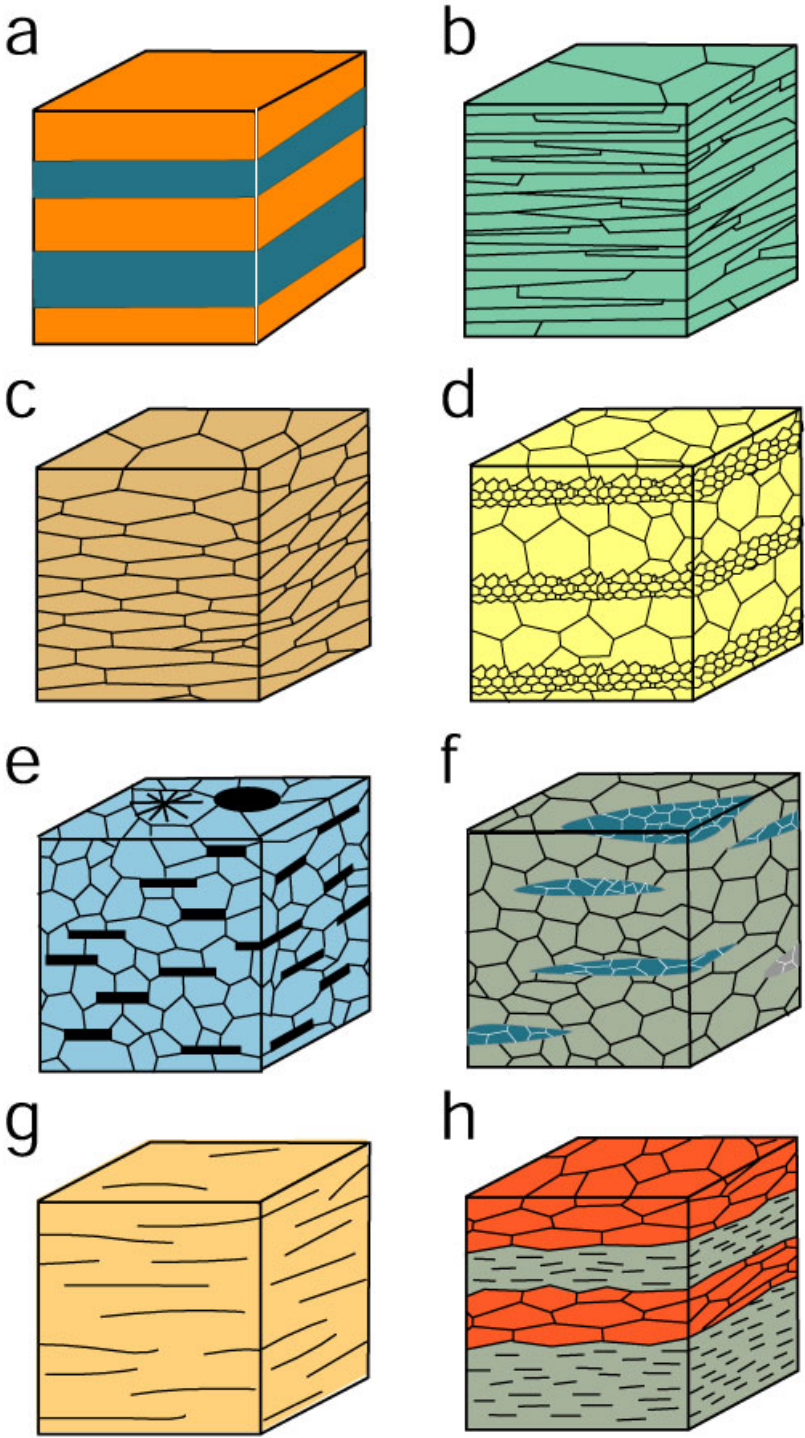
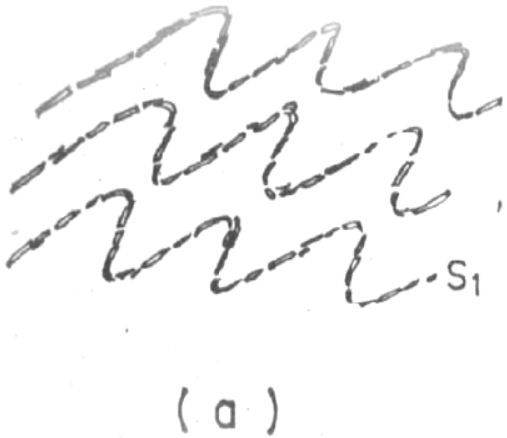
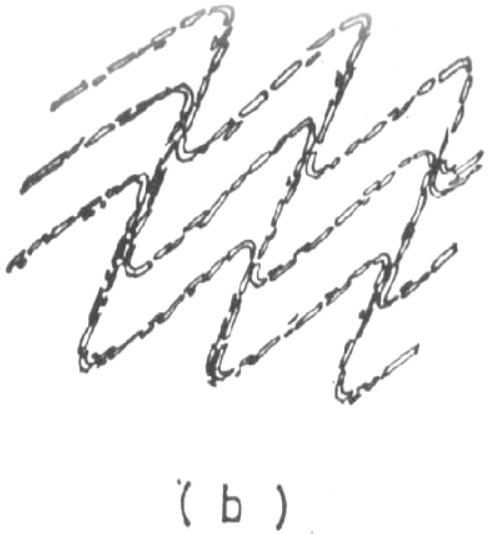
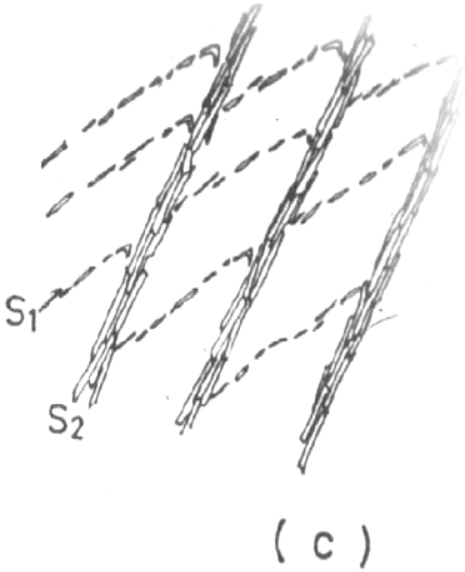


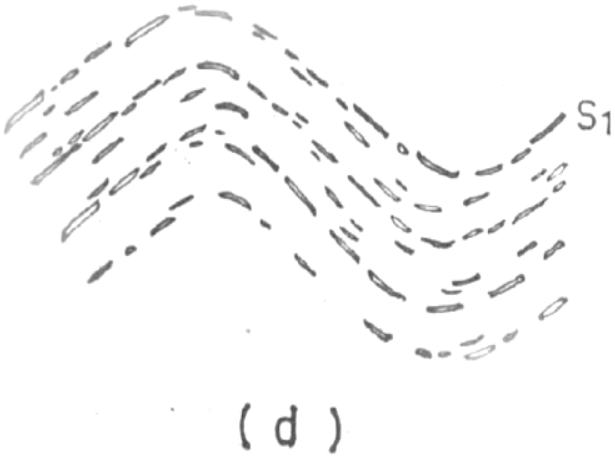
Figure 23.21. Types of fabric elements that may define a foliation. From Turner and Weiss (1963) and Passchier and Trouw (1996).

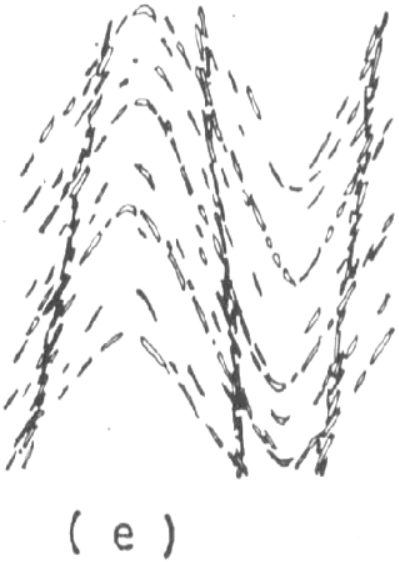


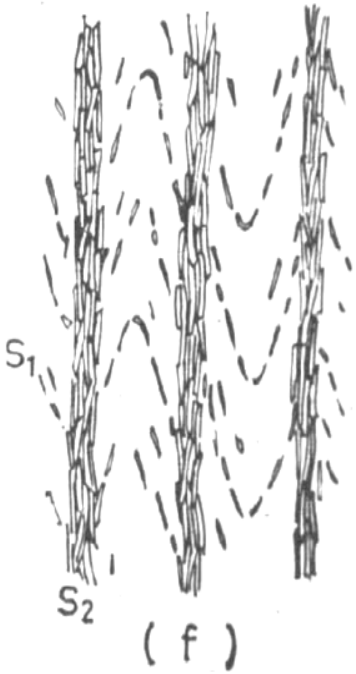




Desenvolvimento progressivo de foliação (a -> f) From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.







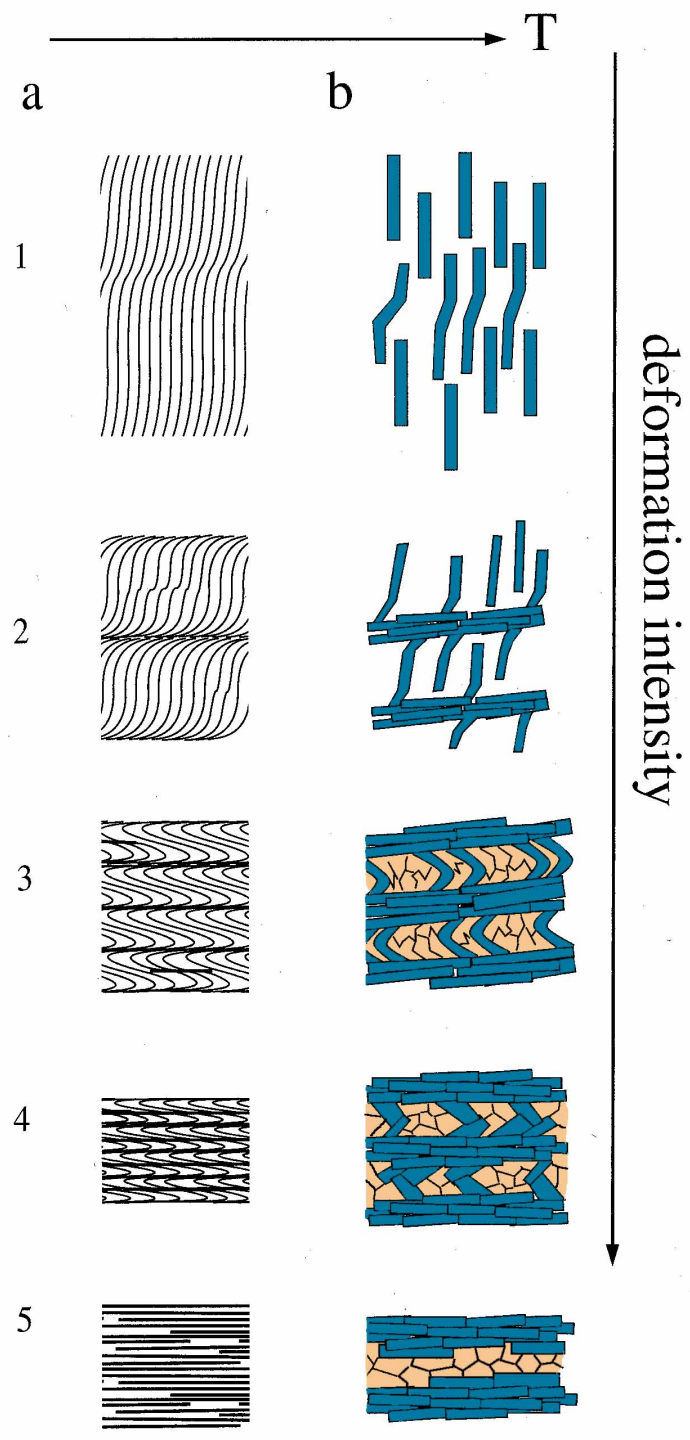


Figure 23.25. Stages in the development of crenulation cleavage as a function of temperature and intensity of the second deformation. From Passchier and Trouw (1996) *Microtectonics*. Springer-Verlag.

Desenvolvimento de clivagem de crenulação e transposição de foliação (depende do grau de deformação e da temperatura).

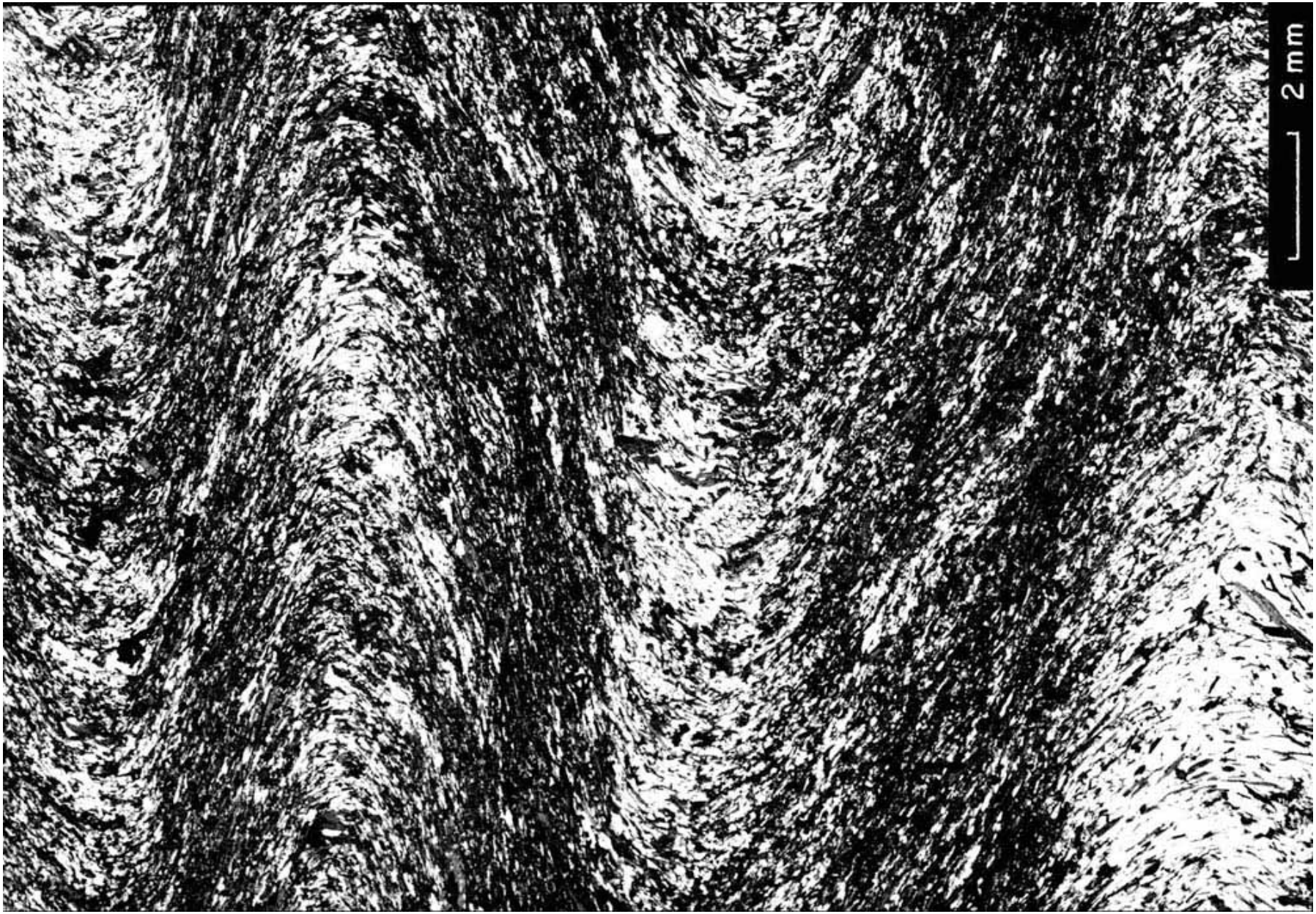


Figure 23.24a. Symmetrical crenulation cleavages in amphibole-quartz-rich schist. Note concentration of quartz in hinge areas. From Borradaile *et al*. (1982) *Atlas of Deformational and Metamorphic Rock Fabrics*. Springer-Verlag.

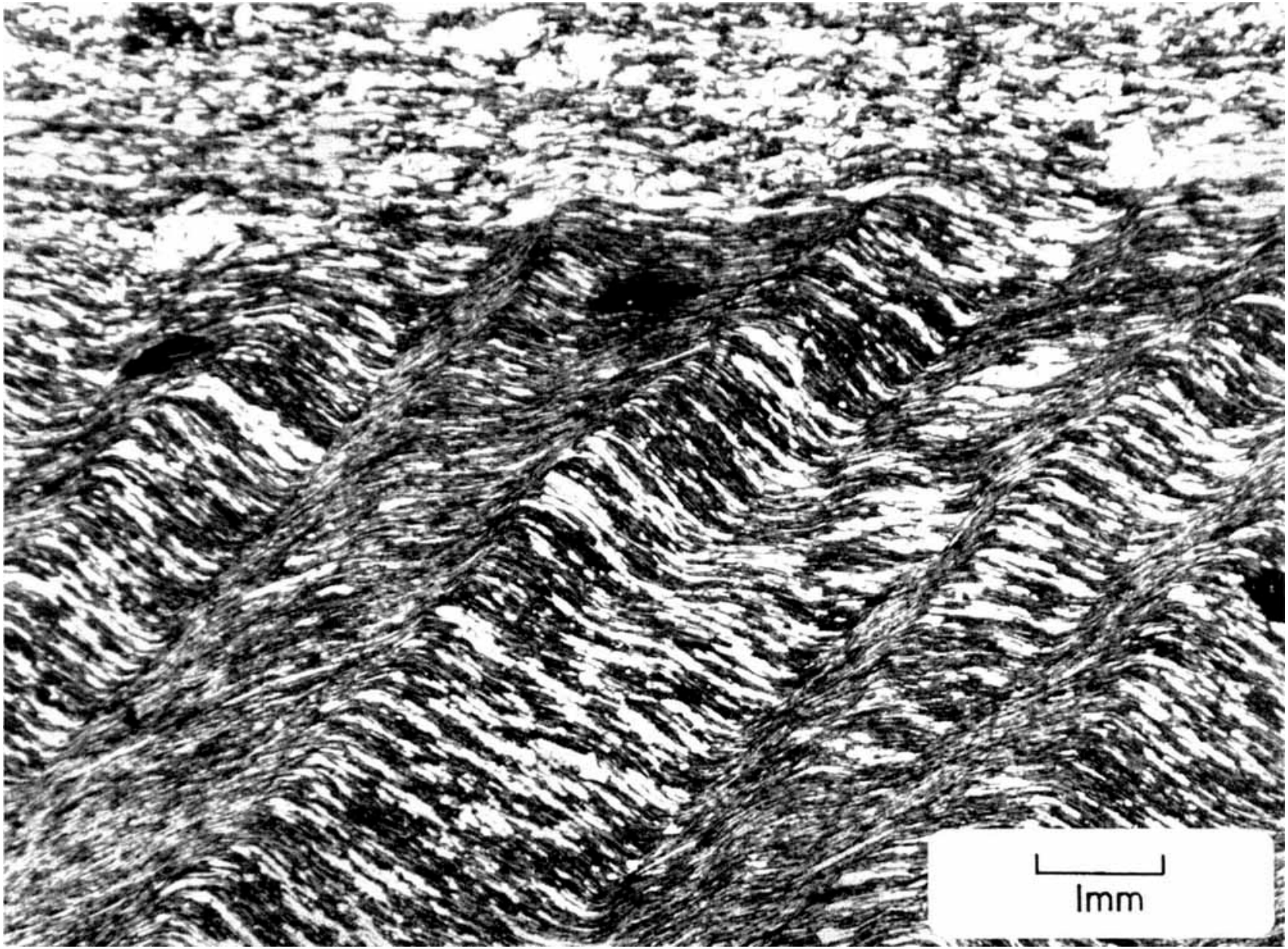


Figure 23.24b. Asymmetric crenulation cleavages in mica-quartz-rich schist. Note horizontal compositional layering (relict bedding) and preferential dissolution of quartz from one limb of the folds. From Borradaile *et al*. (1982) *Atlas of Deformational and Metamorphic Rock Fabrics*. Springer-Verlag.

Tipos de lineação

a. Orientação preferencial de agregados alongados

b. orientação preferencial de minerais prismáticos alongados (e.g. turmalina)

c. lineação de minerais micáceos (definida pelo eixo de zona da orientação das placas de mica)

d. Eixos de dobra (ou de crenulações)

e. Lineação de intersecção de elementos planares.

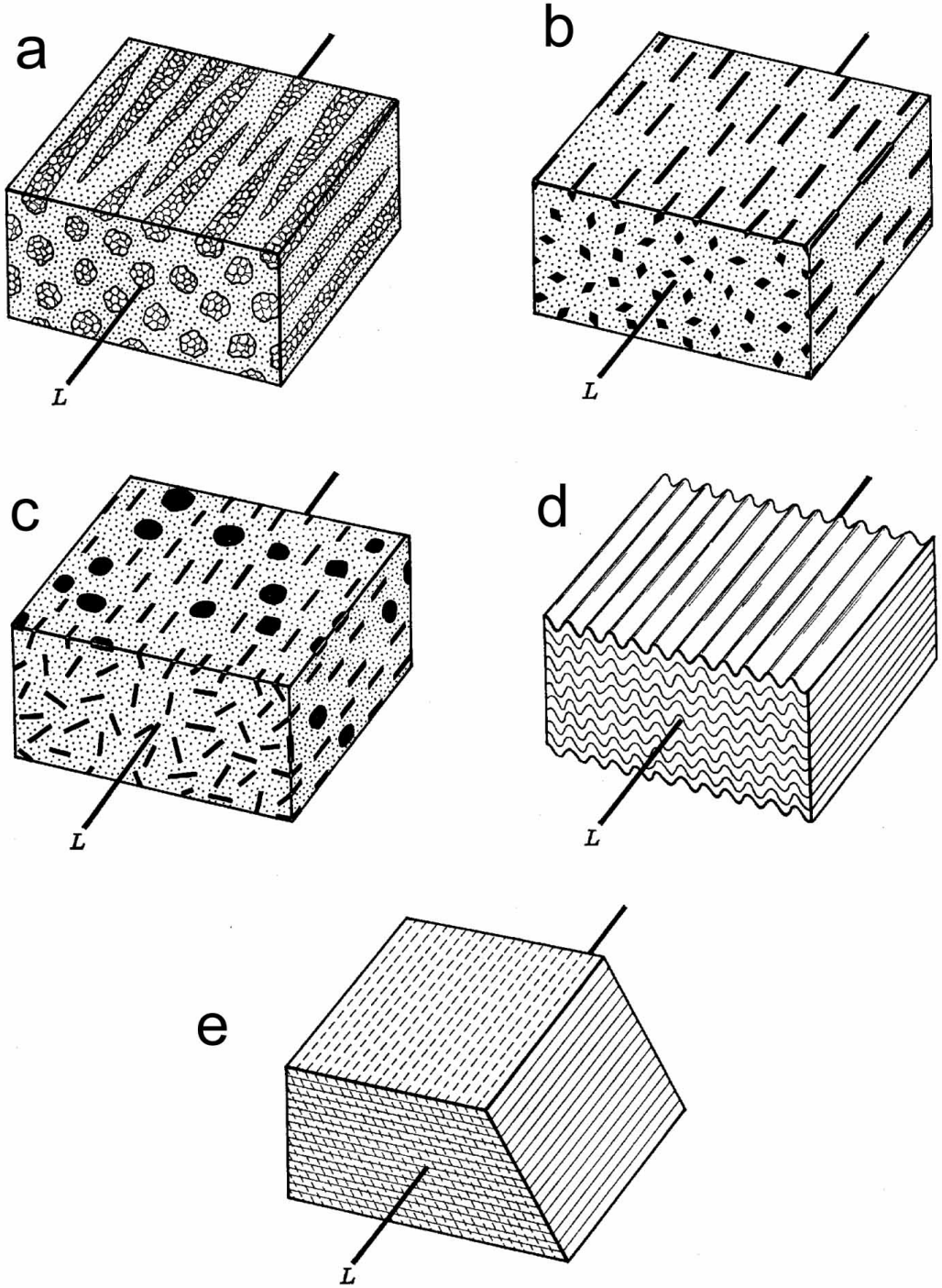


Figure 23.26. Types of fabric elements that define a lineation. From Turner and Weiss (1963) *Structural Analysis of Metamorphic Tectonites.* McGraw Hill.

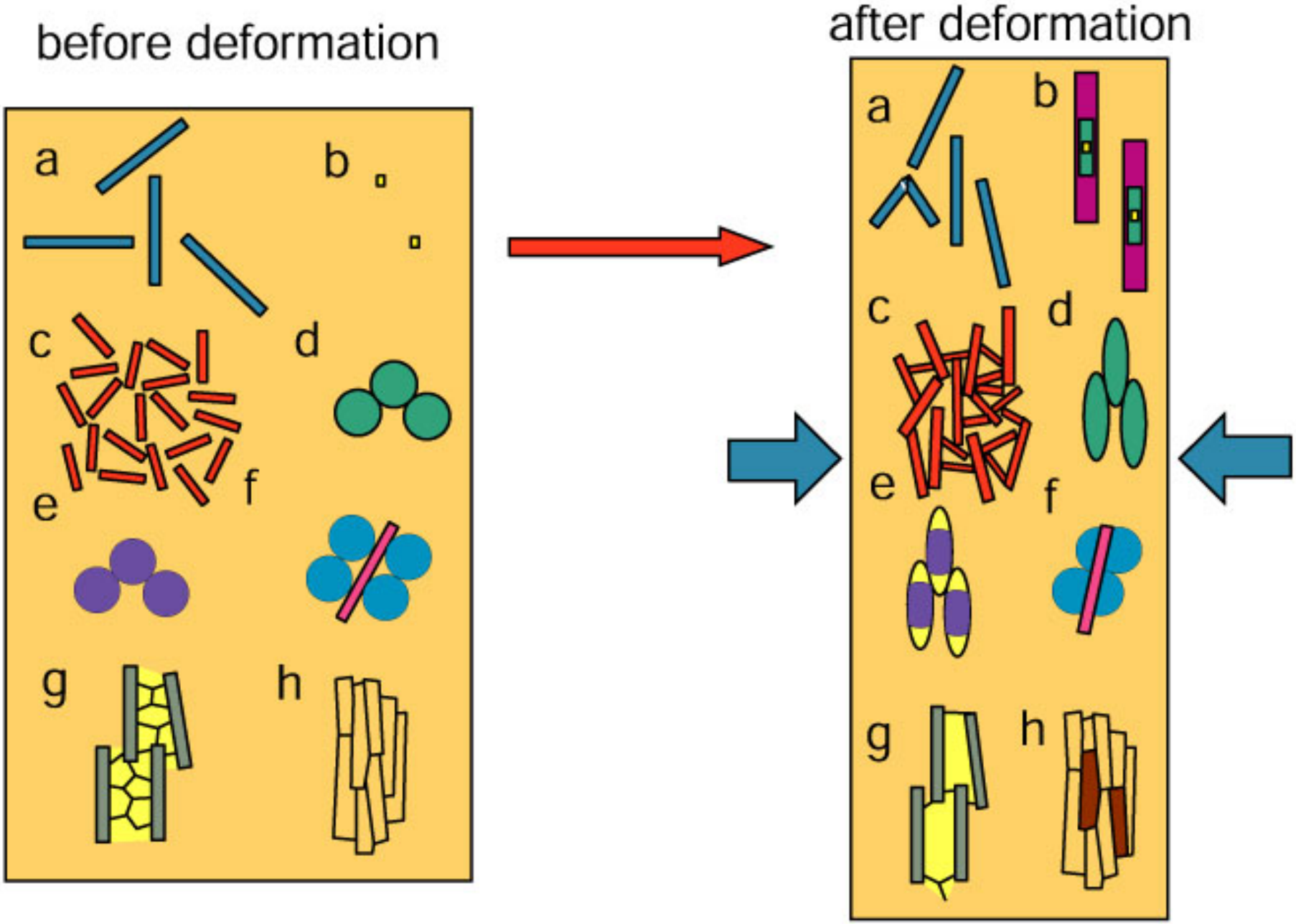


Figure 23.27. **Proposed mechanisms for the development of foliations. After Passchier and Trouw (1996) Microtectonics. Springer-Verlag.**

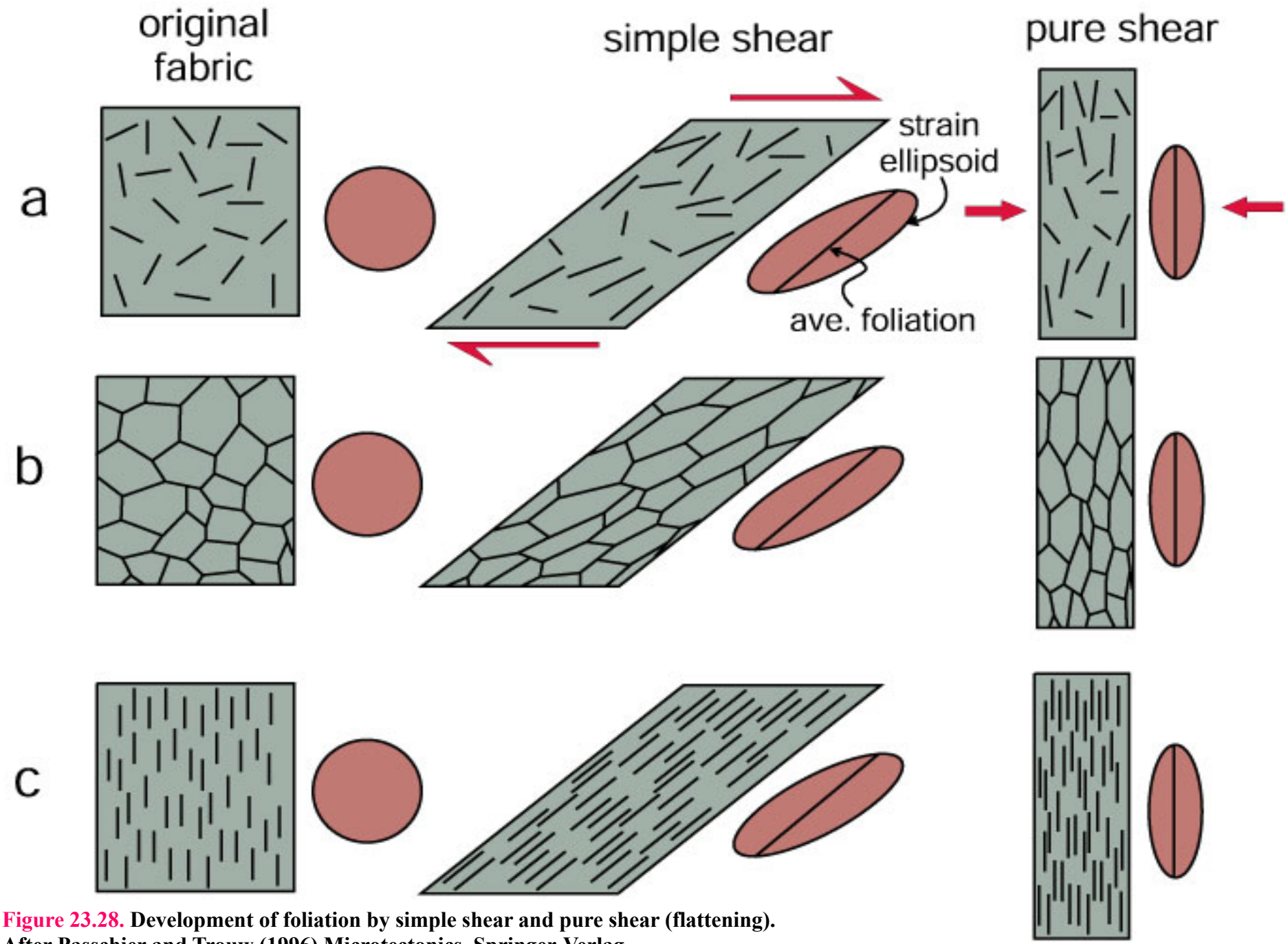
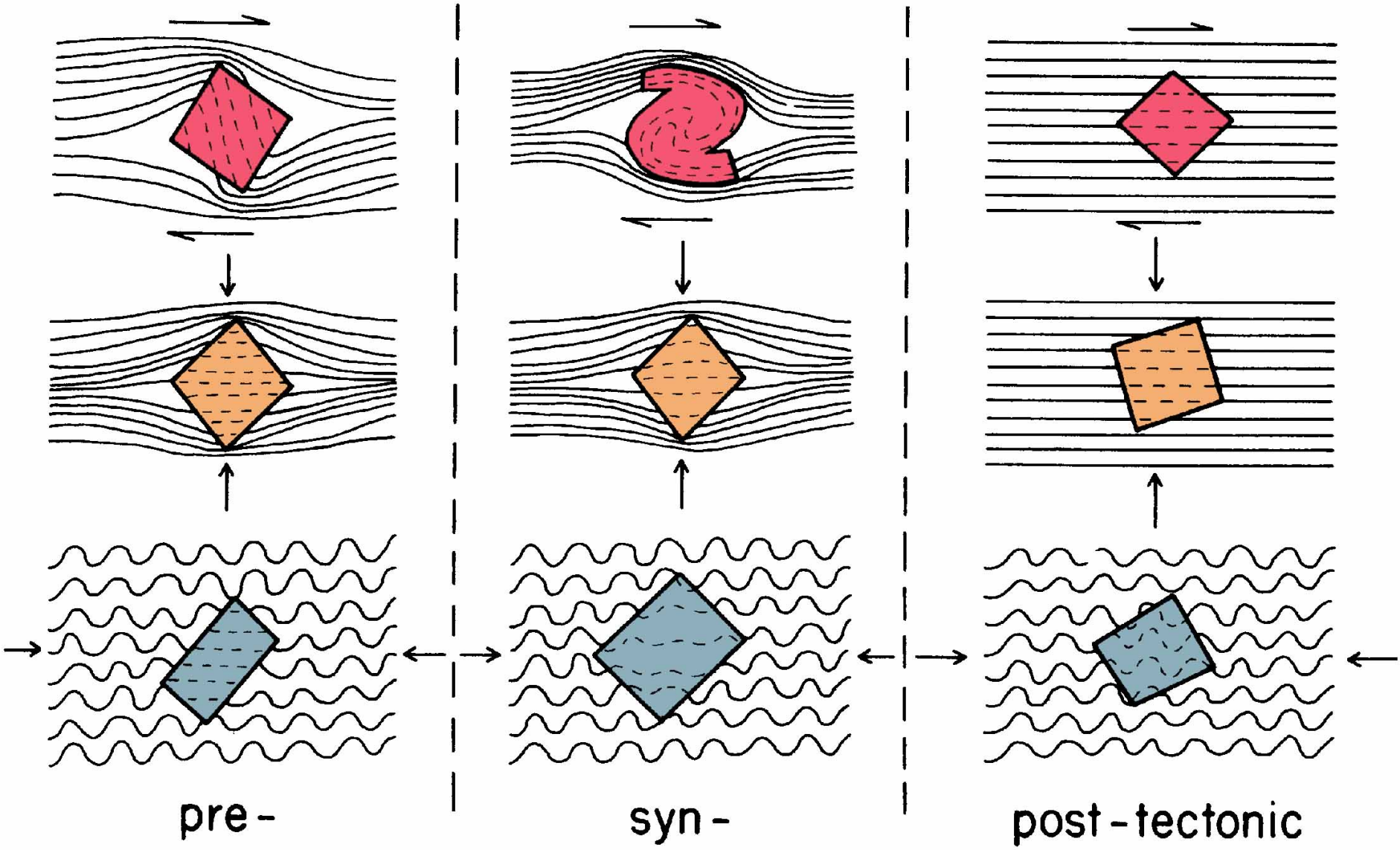


Figure 23.28. **Development of foliation by simple shear and pure shear (flattening). After Passchier and Trouw (1996) Microtectonics. Springer-Verlag.**

História de deformação por meio de cristais pré-, sin e pós-cinemáticos



Cristais pré-cinemáticos

a. Curvo com extinção ondulante
b. Envolvido pela foliação metamórfica
c. Com sombras de pressão
d. Kinks ou dobras no cristal (e.g. biotita)
e. Microboudinage
f. Geminação deformada

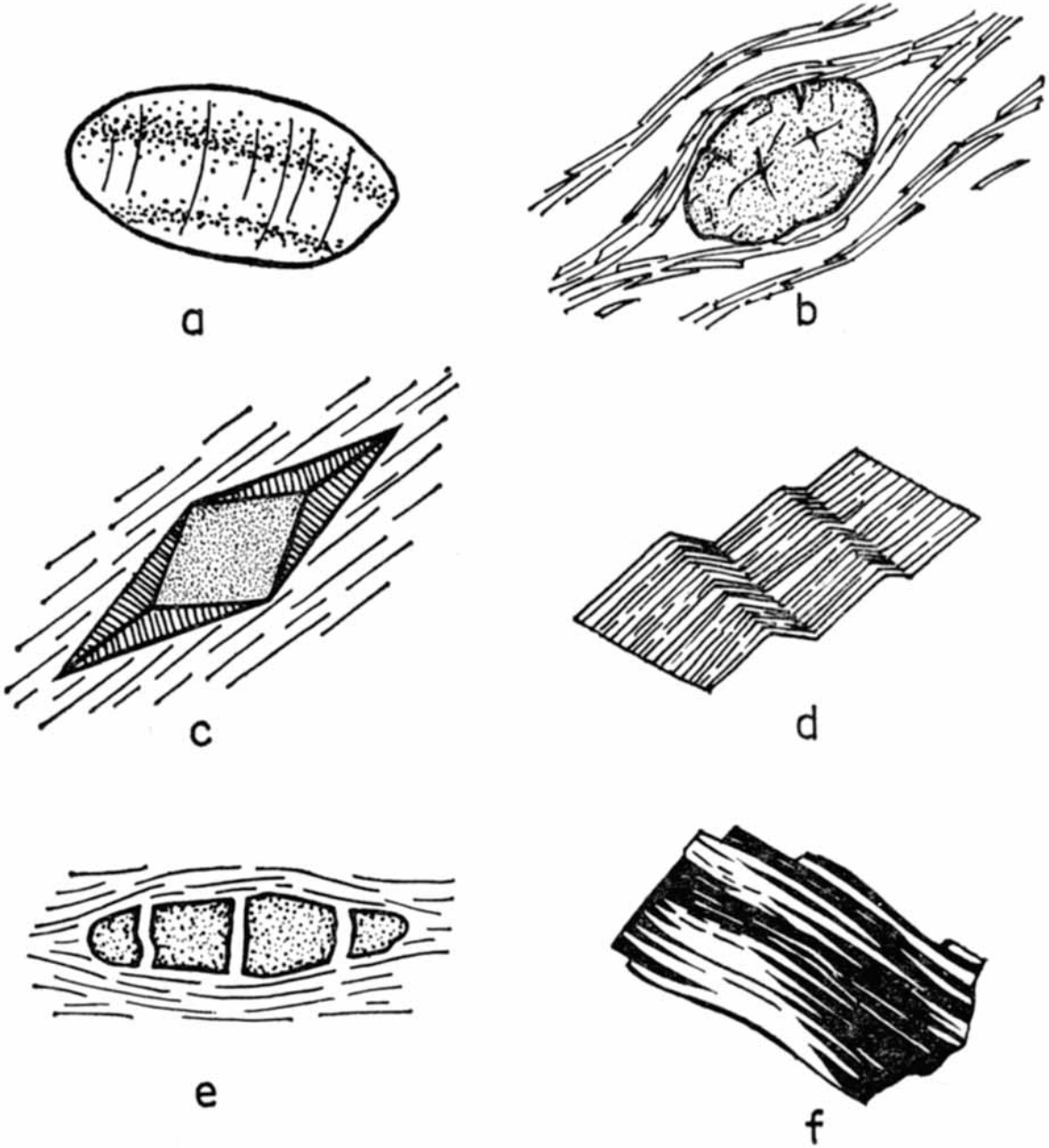


Figure 23.34. Typical textures of pre-kinematic crystals. From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.

Cristais pós-cinemáticos

a. Dobras internas **b.** Cristais orientados aleatoriamente no plano de foliação, **c.** Arcos com textura poligonal, **d.** Cristal englobando a foliação **e.** Porfiroblasto sem inclusões, envolvendo cristal sin-cinemático com inclusões, **f.** pseudomorfo com orientação cristalográfica aleatória.

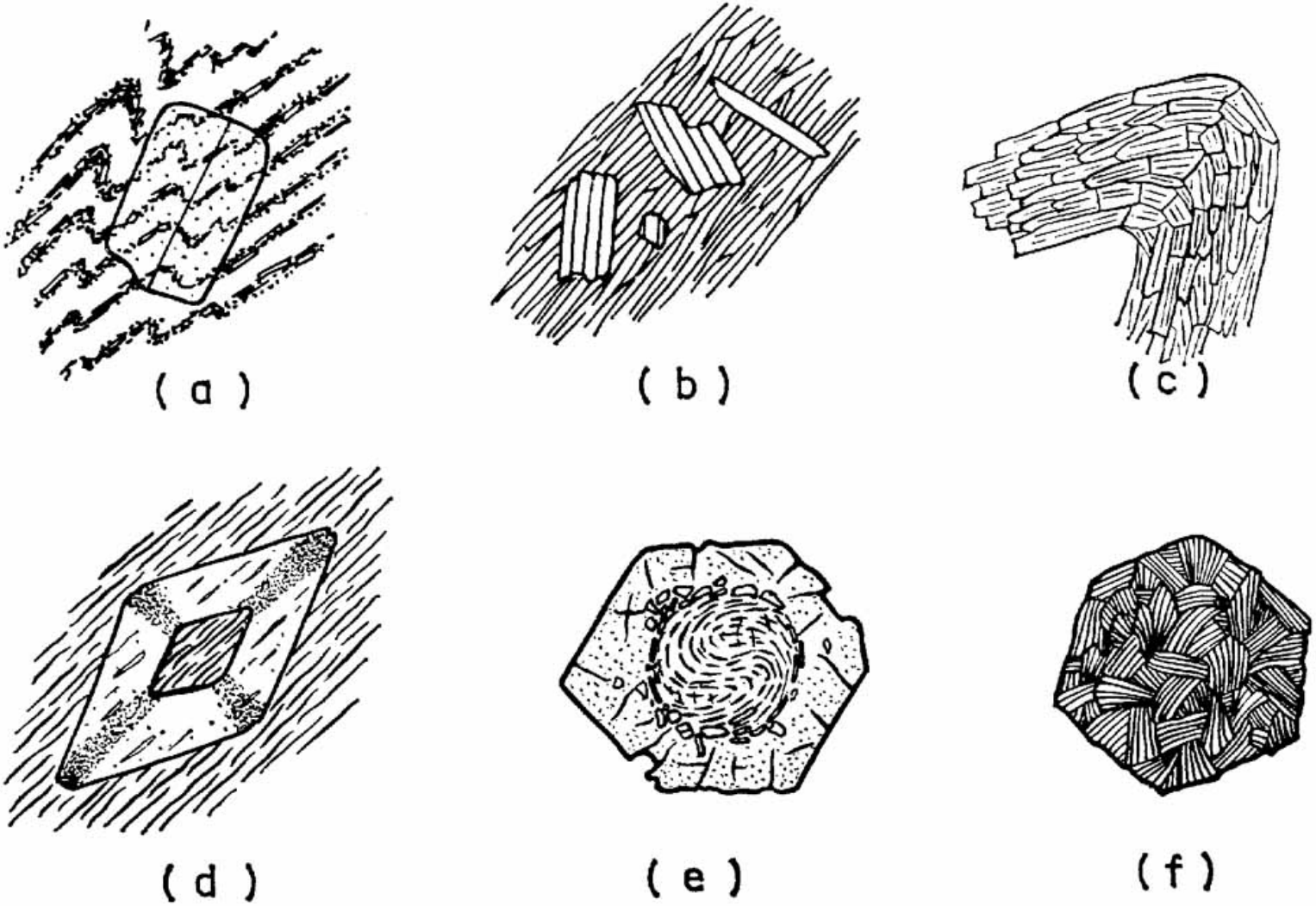
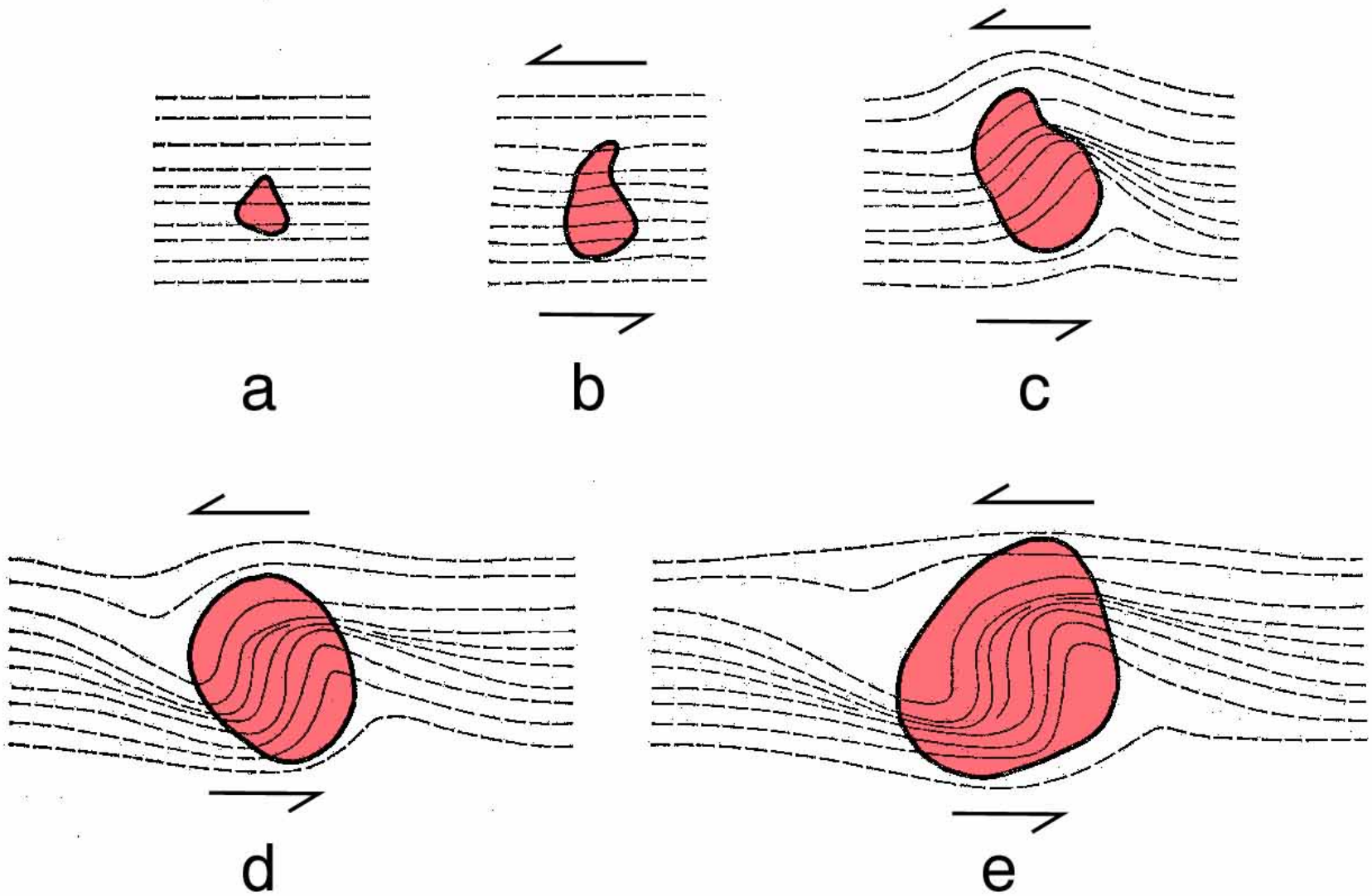


Figure 23.35. **Typical textures of post-kinematic crystals. From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.**

Cristais sin-cinemáticos

Profiroblasto espiralado



Granada com trilha de inclusões em “z”

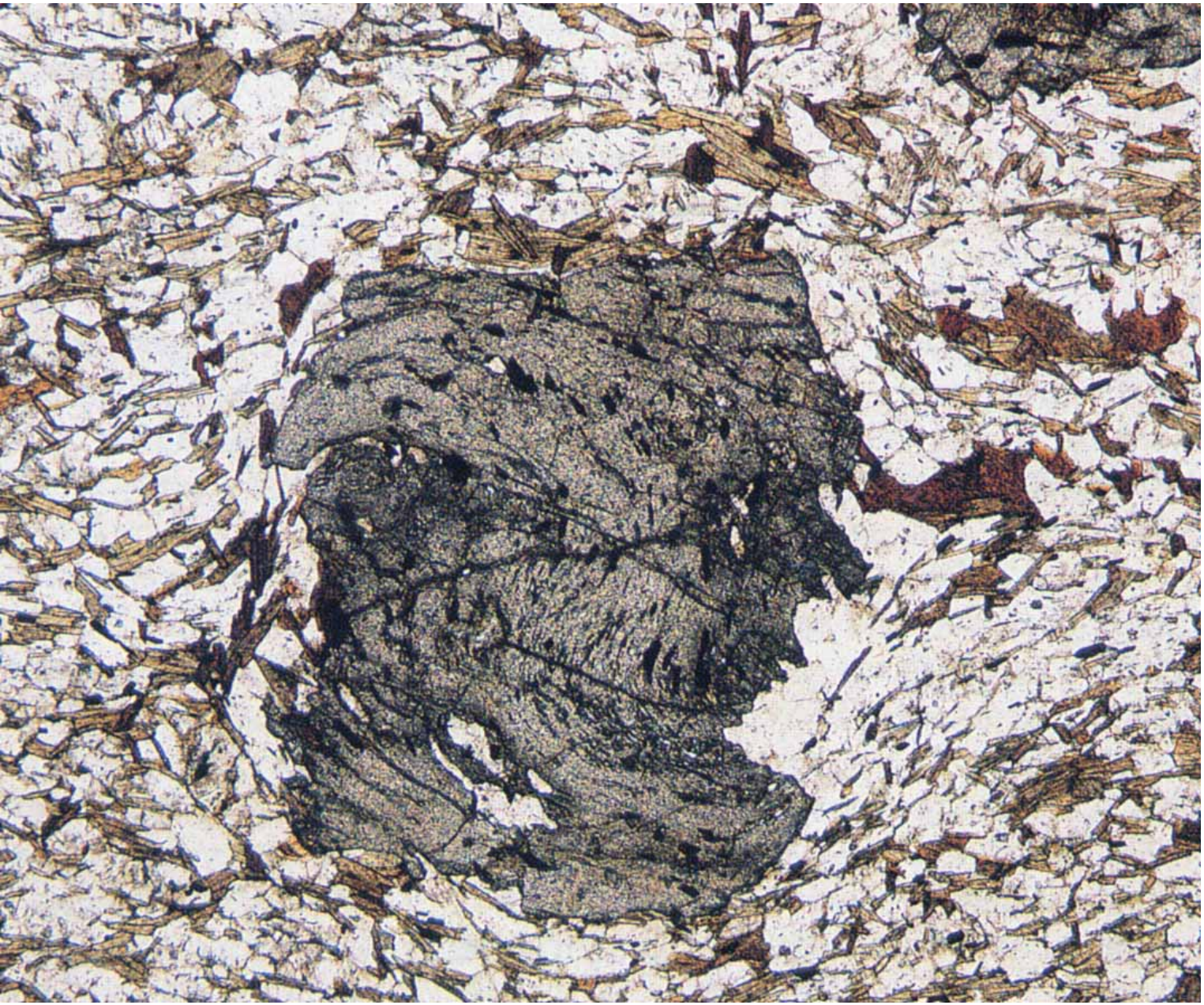


Figure 23.38. **Spiral S_i train in garnet, Connemara, Ireland. Magnification ~20X. From Yardley *et al.* (1990) *Atlas of Metamorphic Rocks and their Textures*. Longmans.**

Granada “bola de neve” !

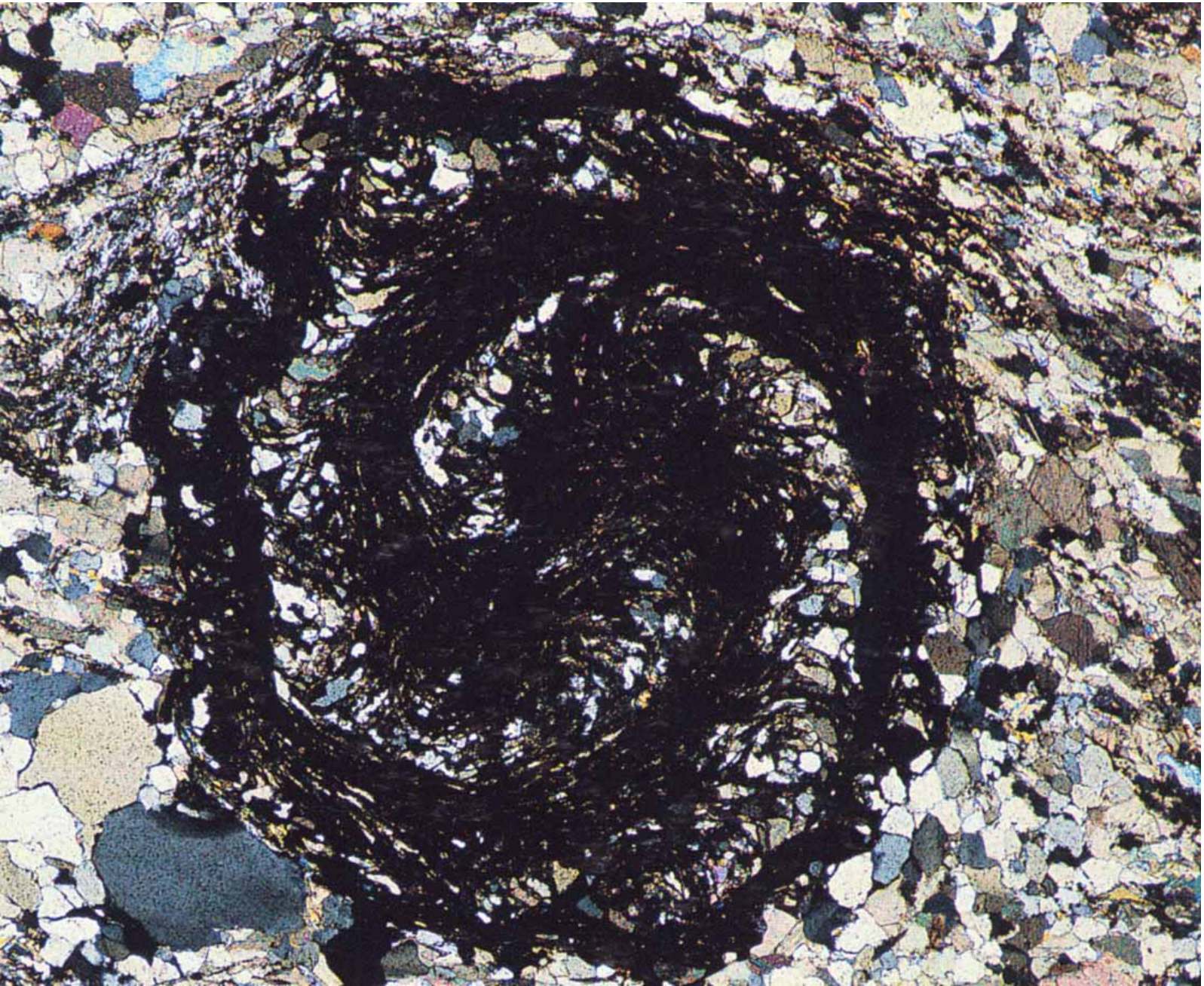
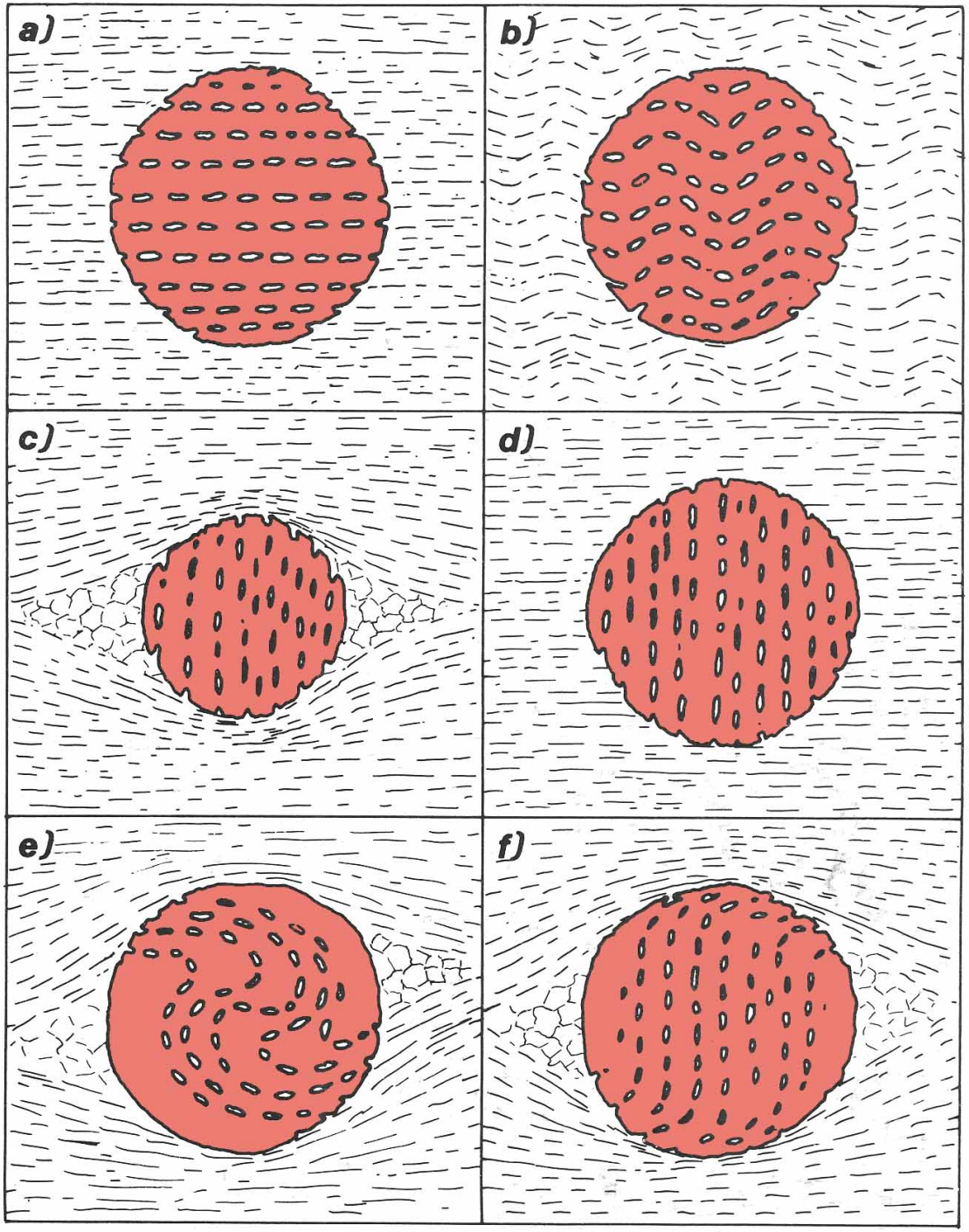


Figure 23.38. **“Snowball garnet” with highly rotated spiral S_i. Porphyroblast is ~ 5 mm in diameter. From Yardley *et al.* (1990) *Atlas of Metamorphic Rocks and their Textures*. Longmans.**



Post-kinematic: **S_i is identical to and continuous with S_e**

Pre-kinematic: **Porphyroblasts are post-S_2. S_i is inherited from an earlier deformation. S_e is compressed about the porphyroblast in (c) and a pressure shadow develops.**

Syn-kinematic: **Rotational porphyroblasts in which S_i is continuous with S_e suggesting that deformation did not outlast porphyroblast growth.**

From Yardley (1989) An Introduction to Metamorphic Petrology. Longman.

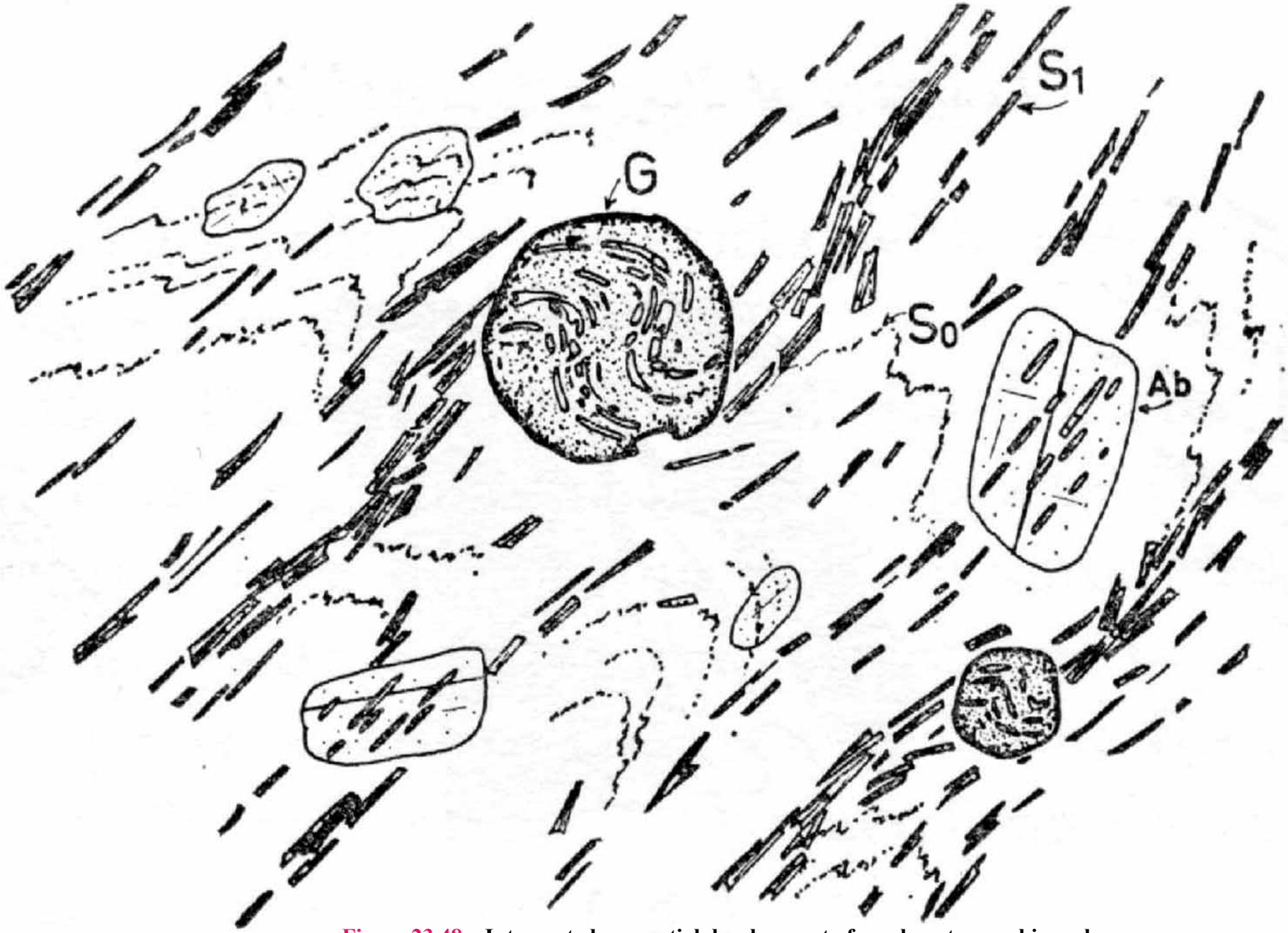


Figure 23.48a. Interpreted sequential development of a polymetamorphic rock. From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.

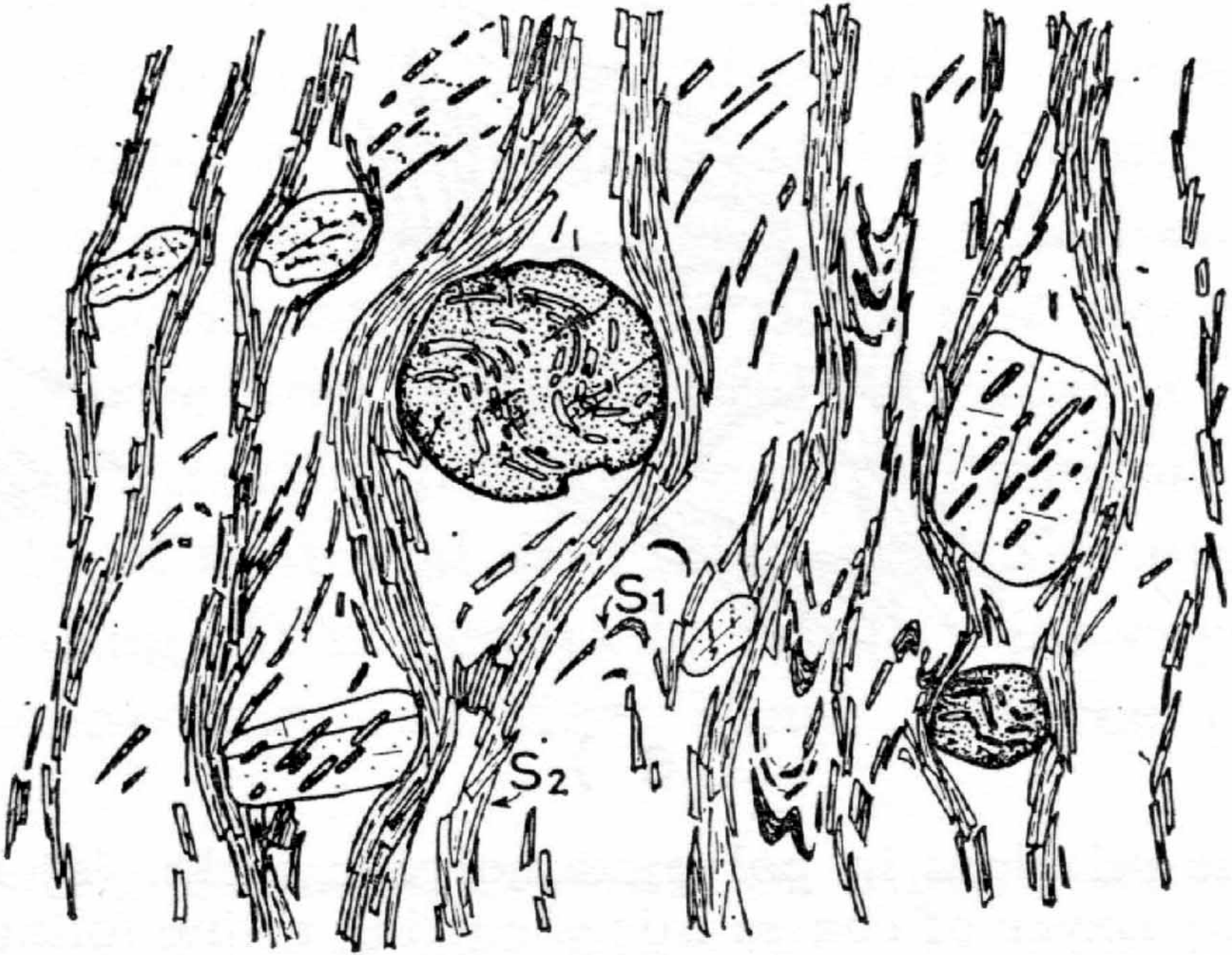


Figure 23.48b. Interpreted sequential development of a polymetamorphic rock. From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.

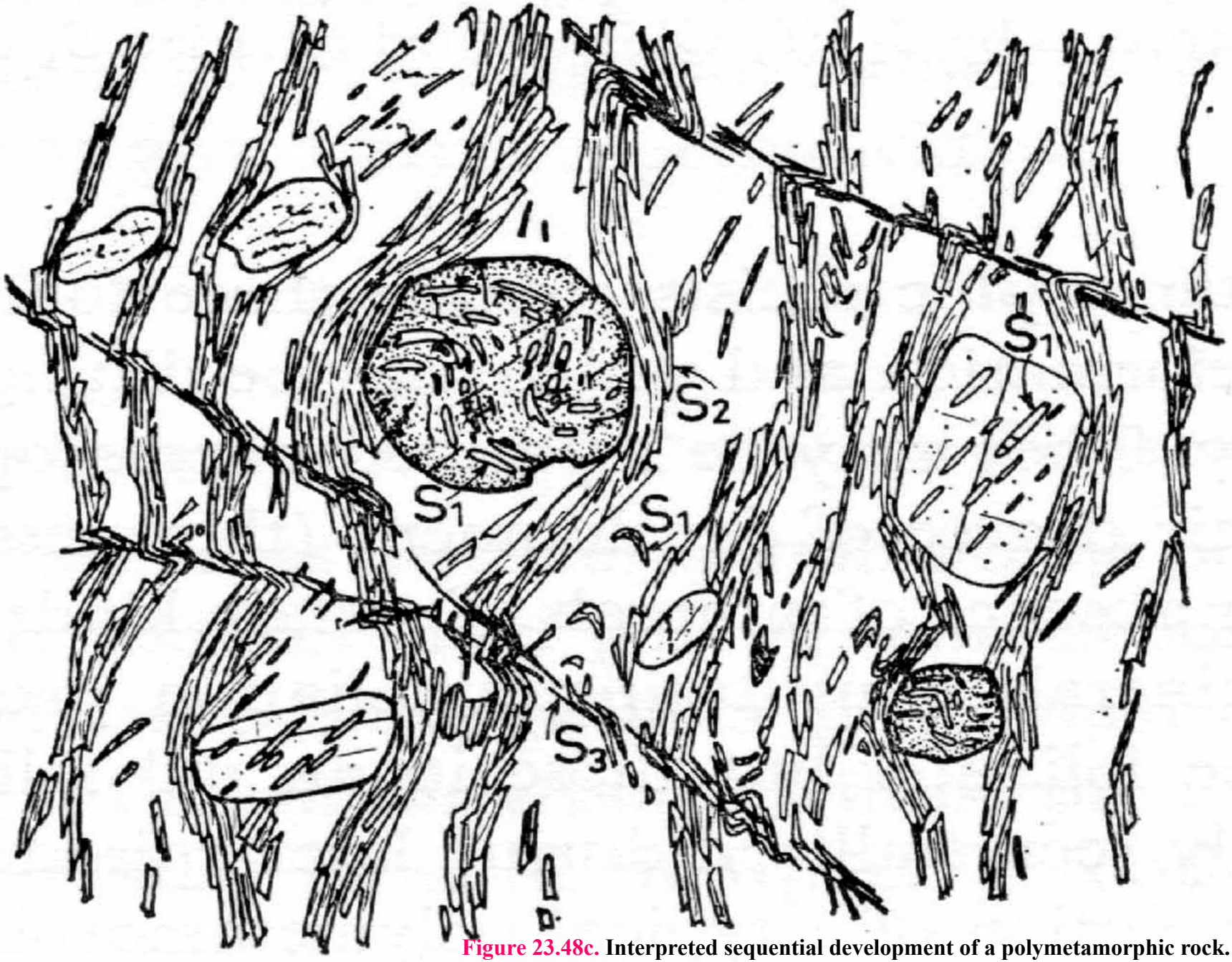


Figure 23.48c. **Interpreted sequential development of a polymetamorphic rock. From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.**

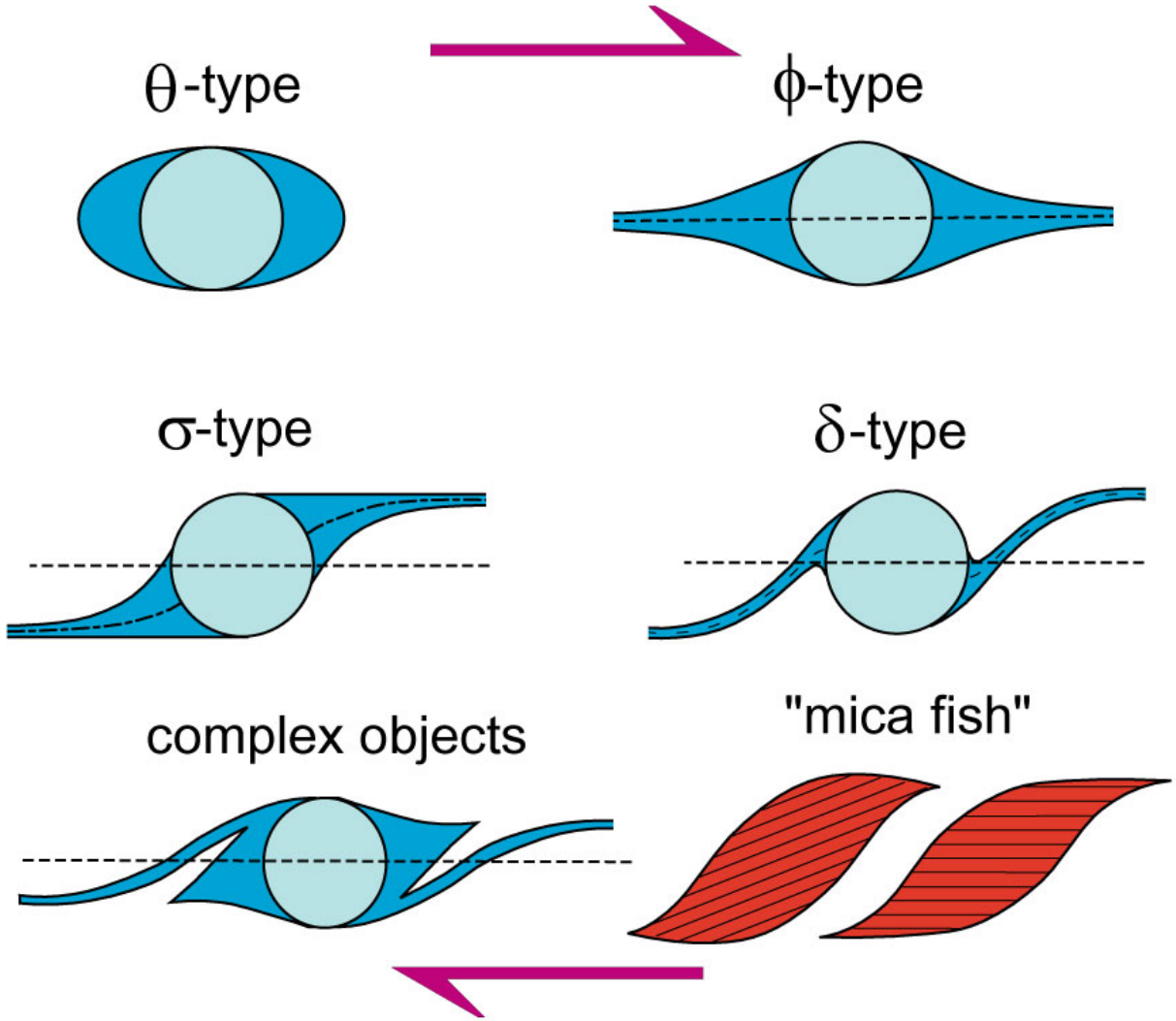


Figure 23.19. **Mantled porphyroclasts and "mica fish" as sense-of-shear indicators. After Passchier and Simpson (1986) Porphyroclast systems as kinematic indicators. *J. Struct. Geol.*, 8, 831-843.**

Agentes de Metamorfismo: Temperatura

- Temperatura: o mais importante fator nos processos metamórficos:

O aumento de T tem os seguintes efeitos:

1) Gera recristalização → aumento no tamanho dos grãos
2) Promove reações químicas
3) Supera barreiras cinéticas

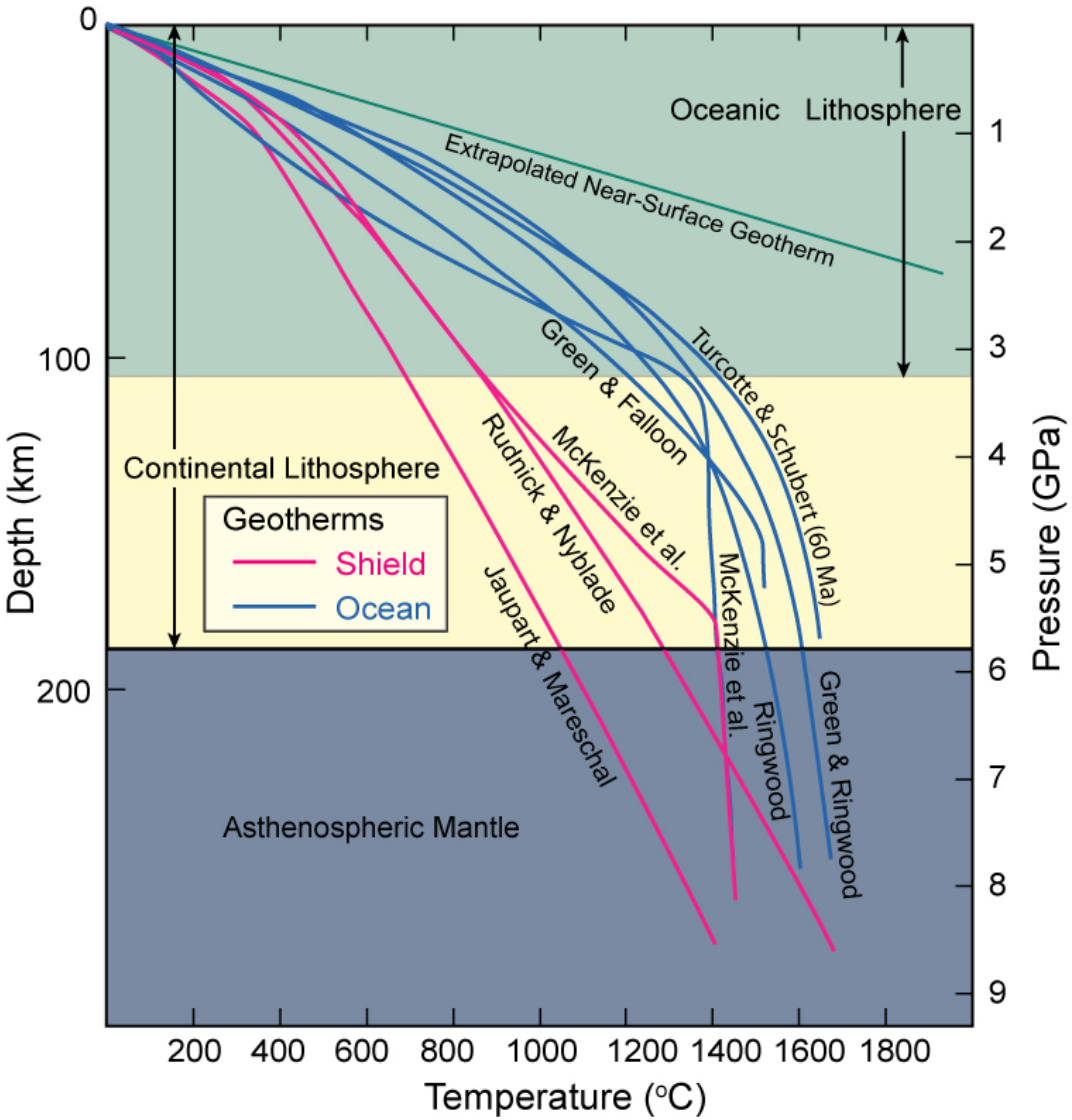
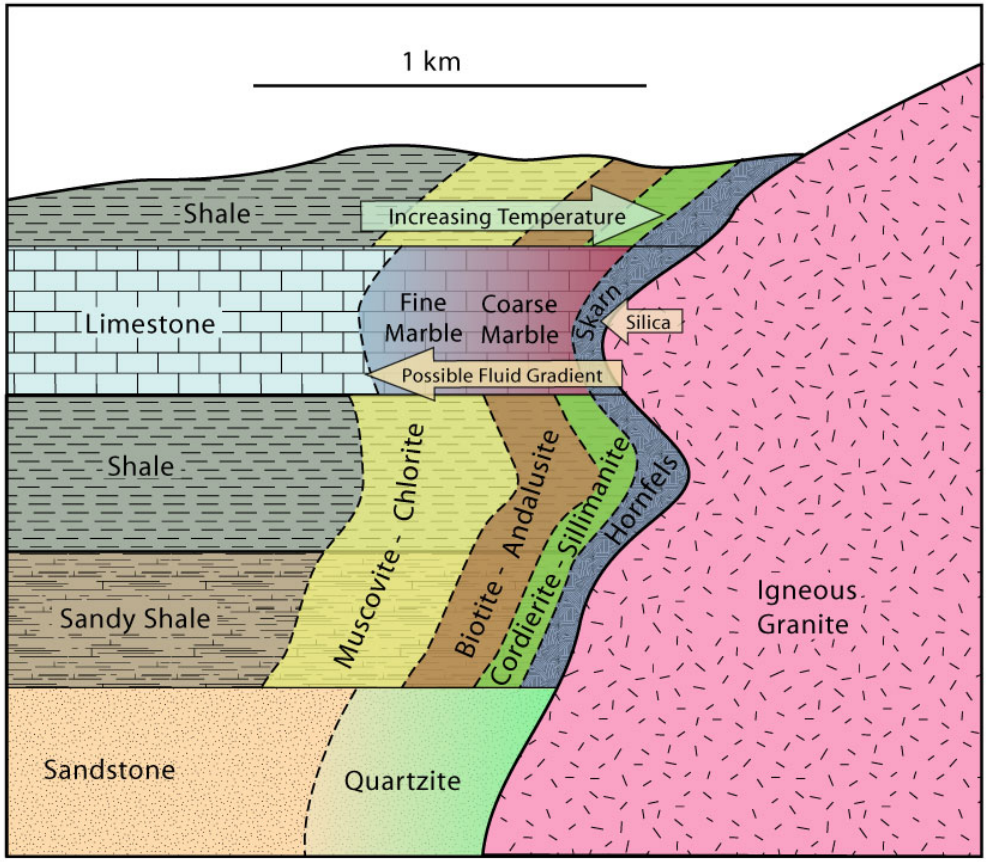
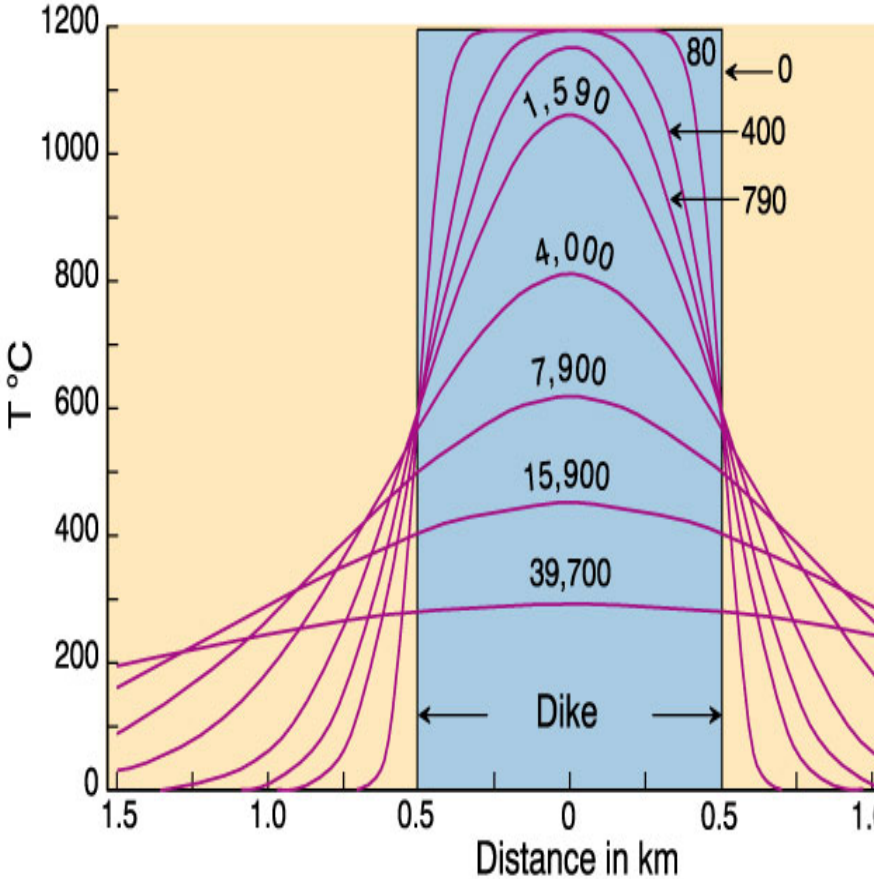


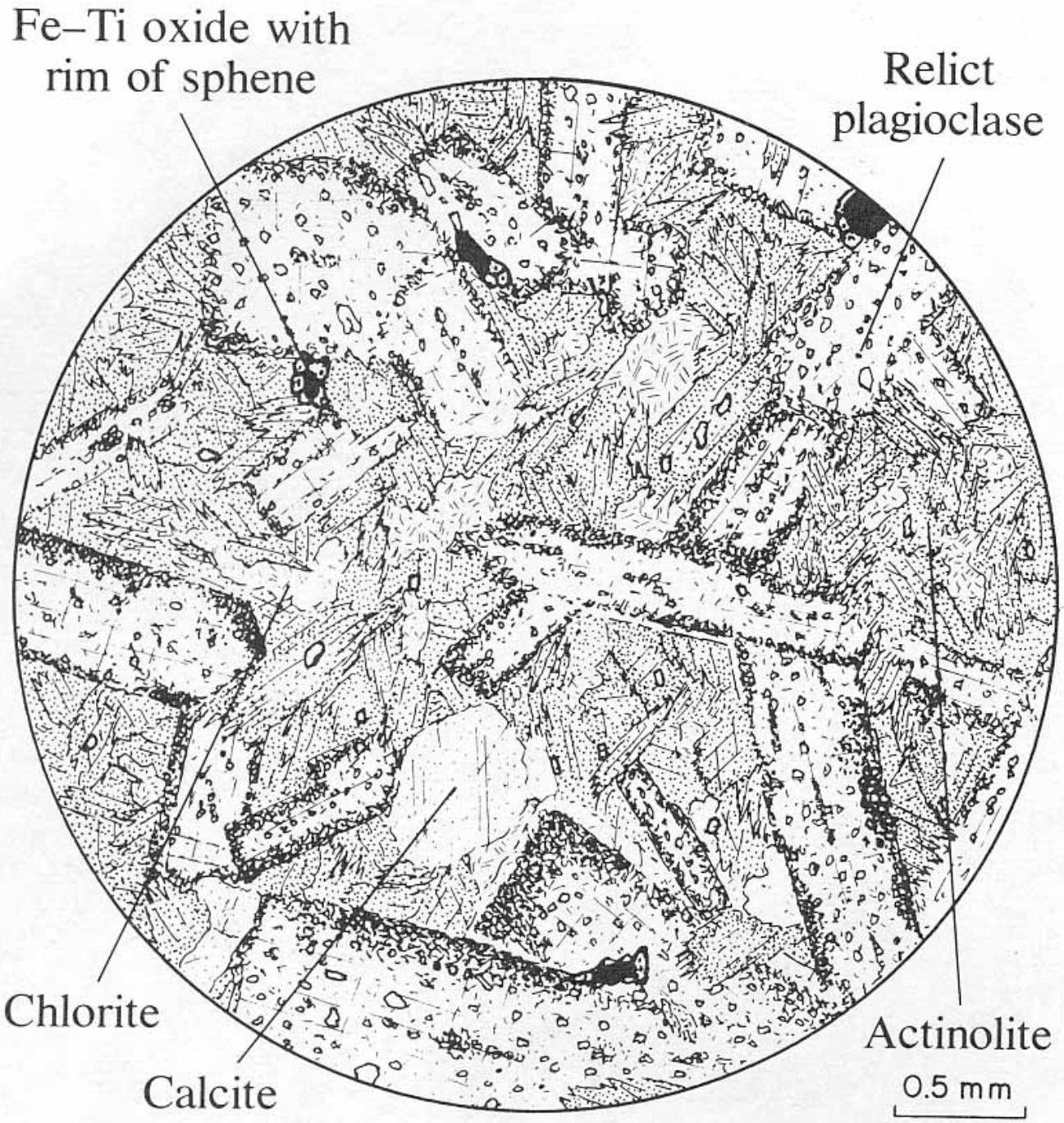
Figure 1.9. Estimated ranges of oceanic and continental steady-state geotherms to a depth of 100 km using upper and lower limits based on he flows measured near the surface. After Sclater *et al*. (1980), Earth. Rev. Geophys. Space Sci., 18, 269-311.

Texturas Metamórficas: Metamorfismo de Contato

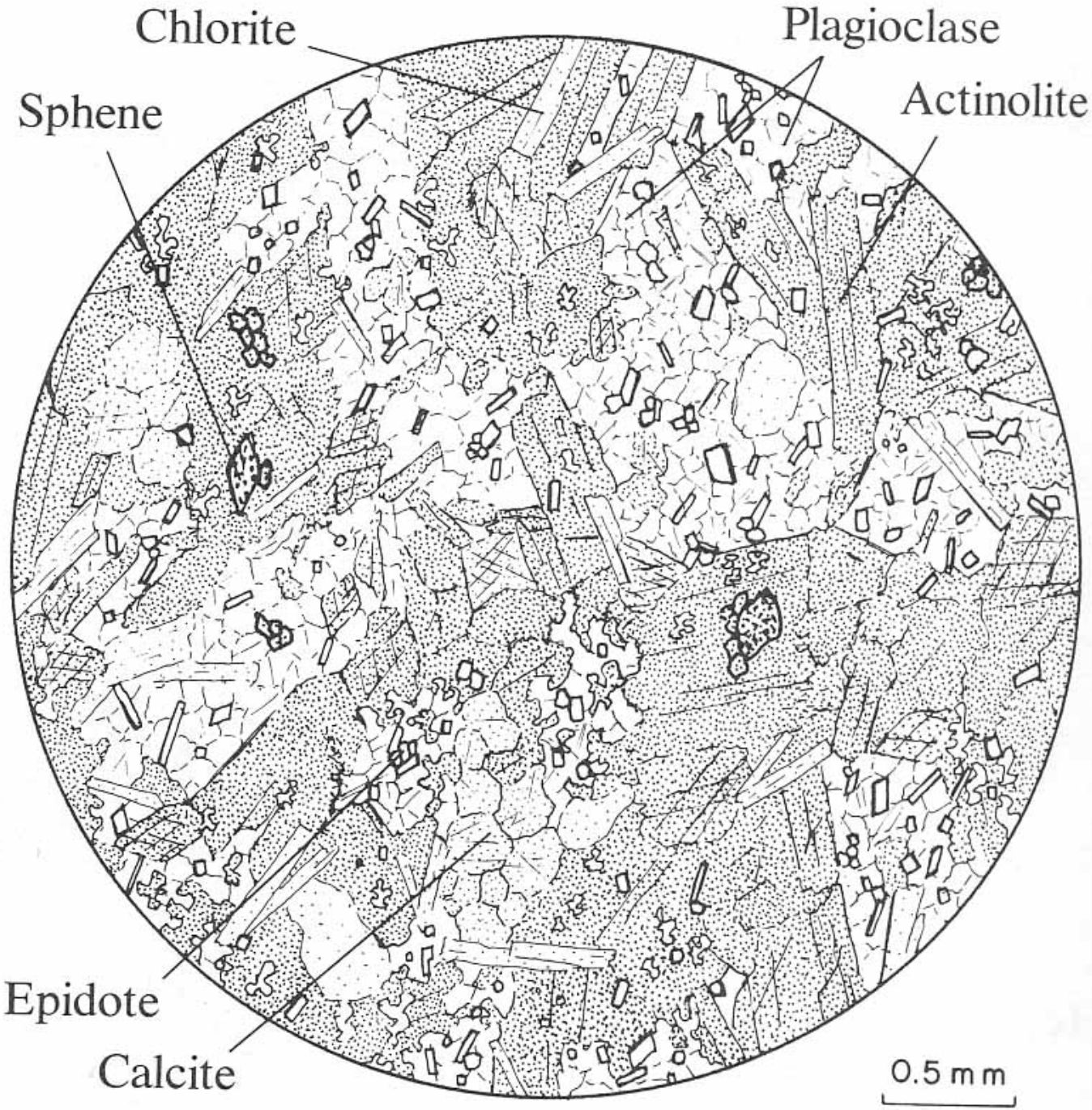
- Situa-se tipicamente em torno de batólitos intrudidos na crosta superior (baixa-P)
- Processos de cristalização/recristalização quase estáticos
- Texturas Isotrópicas (hornfels, granofels)



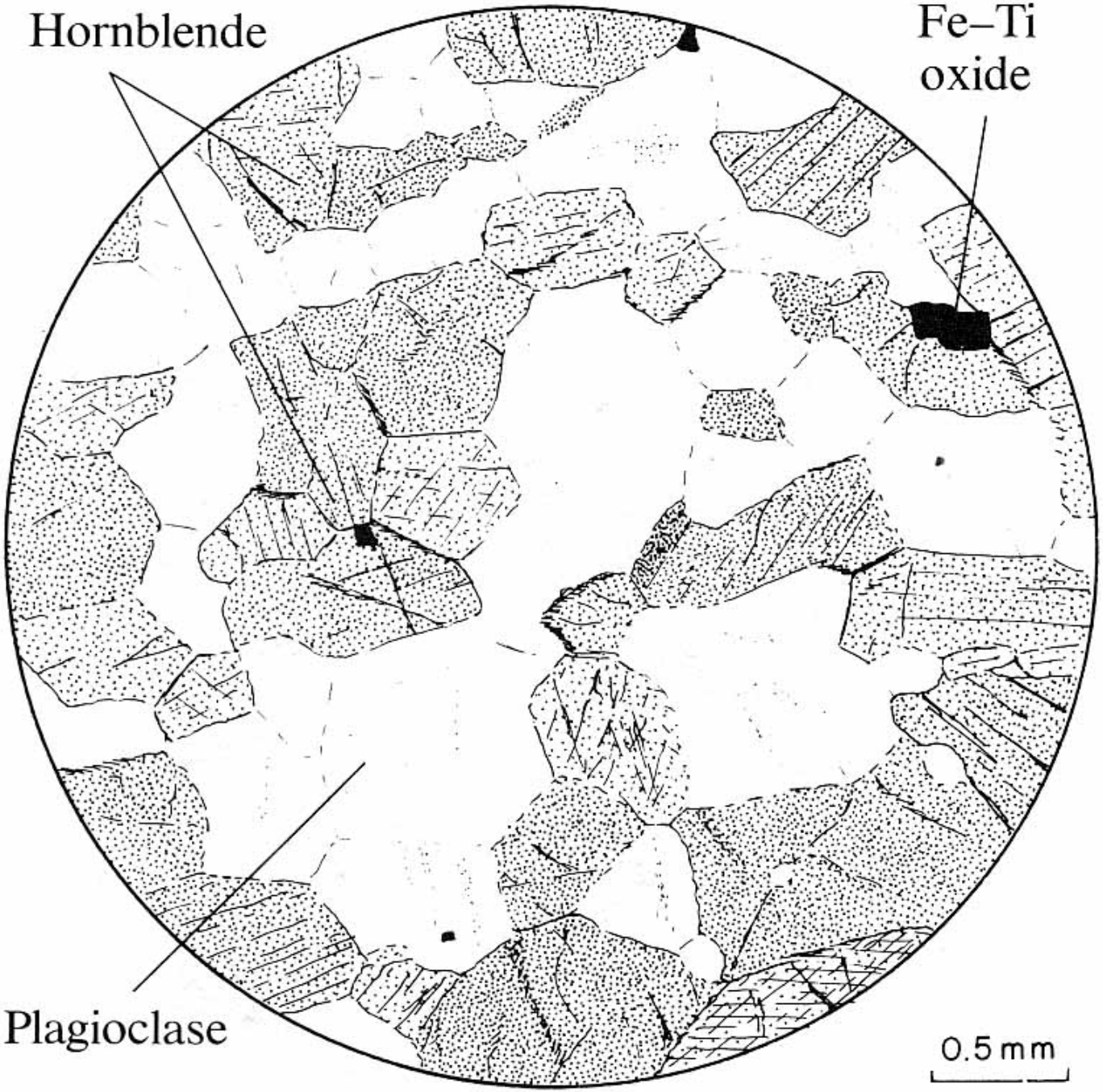




Progressive thermal metamorphism of a diabase (coarse basalt). From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

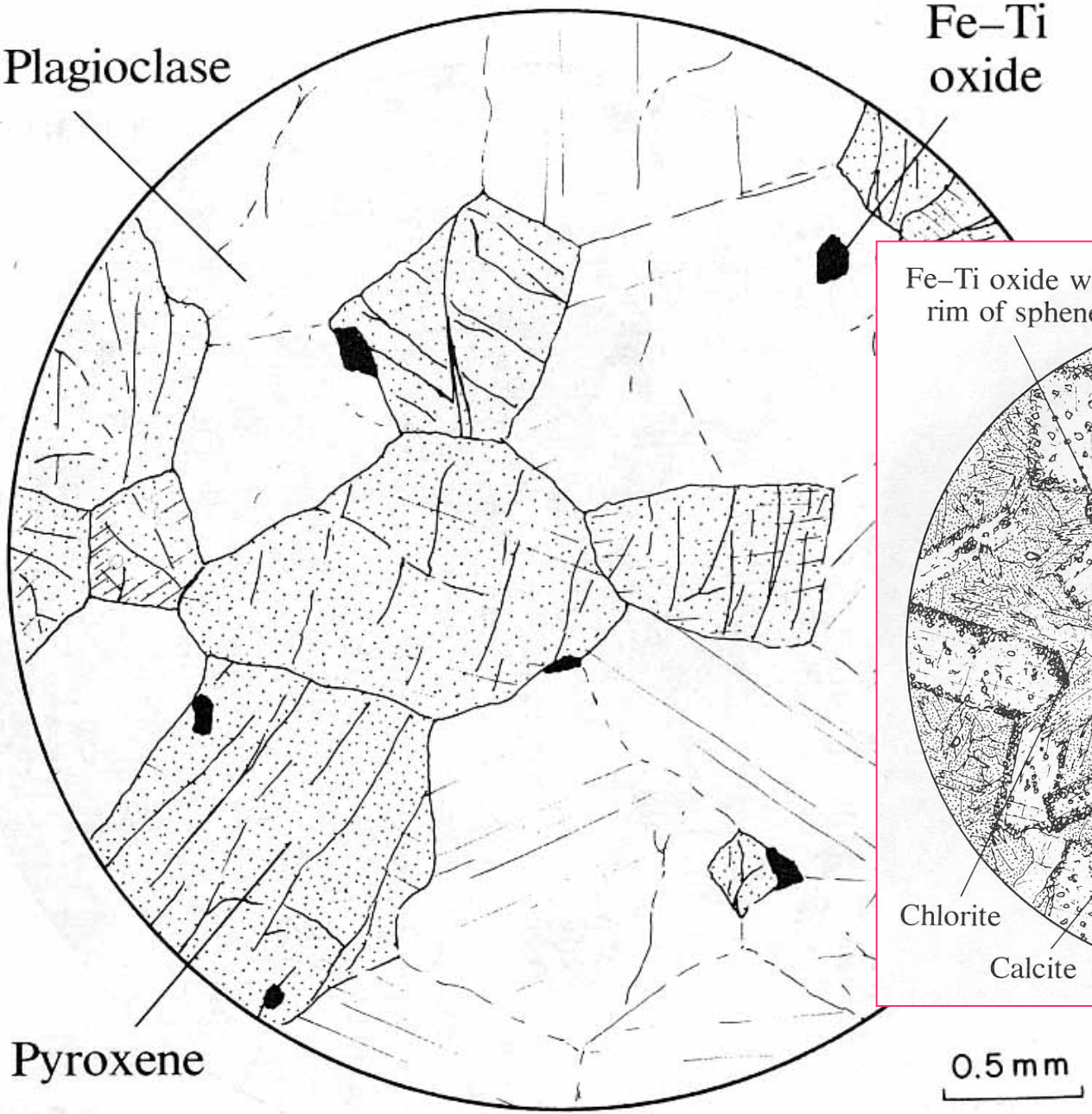


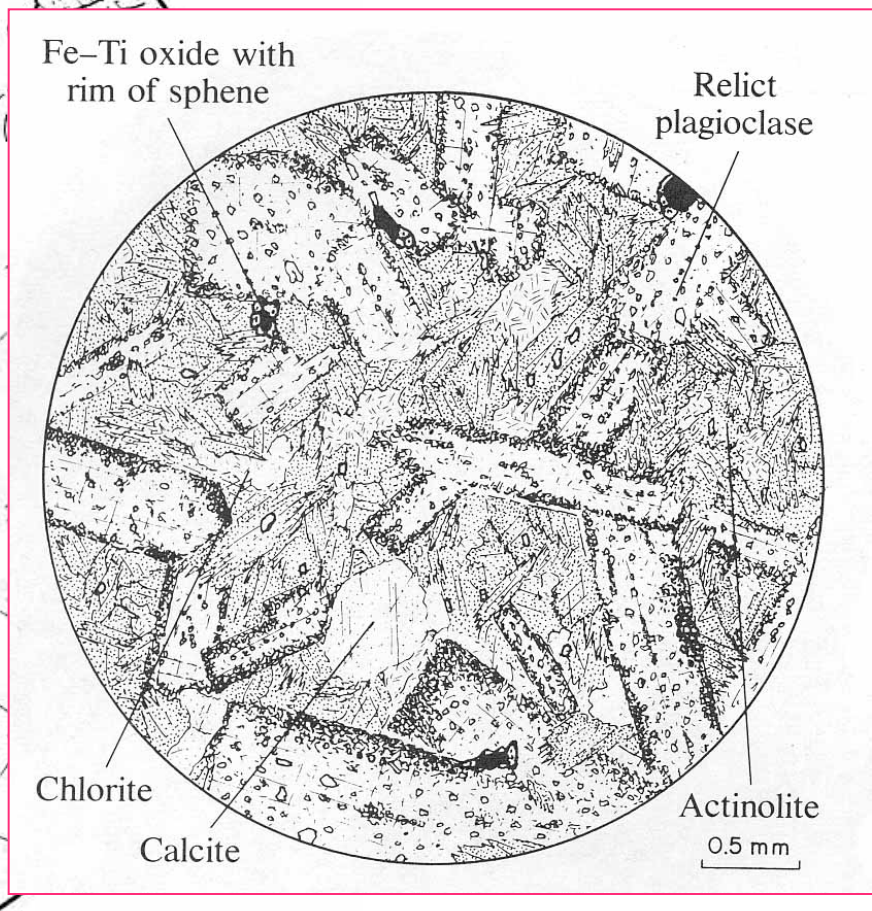
Progressive thermal metamorphism of a diabase (coarse basalt). From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

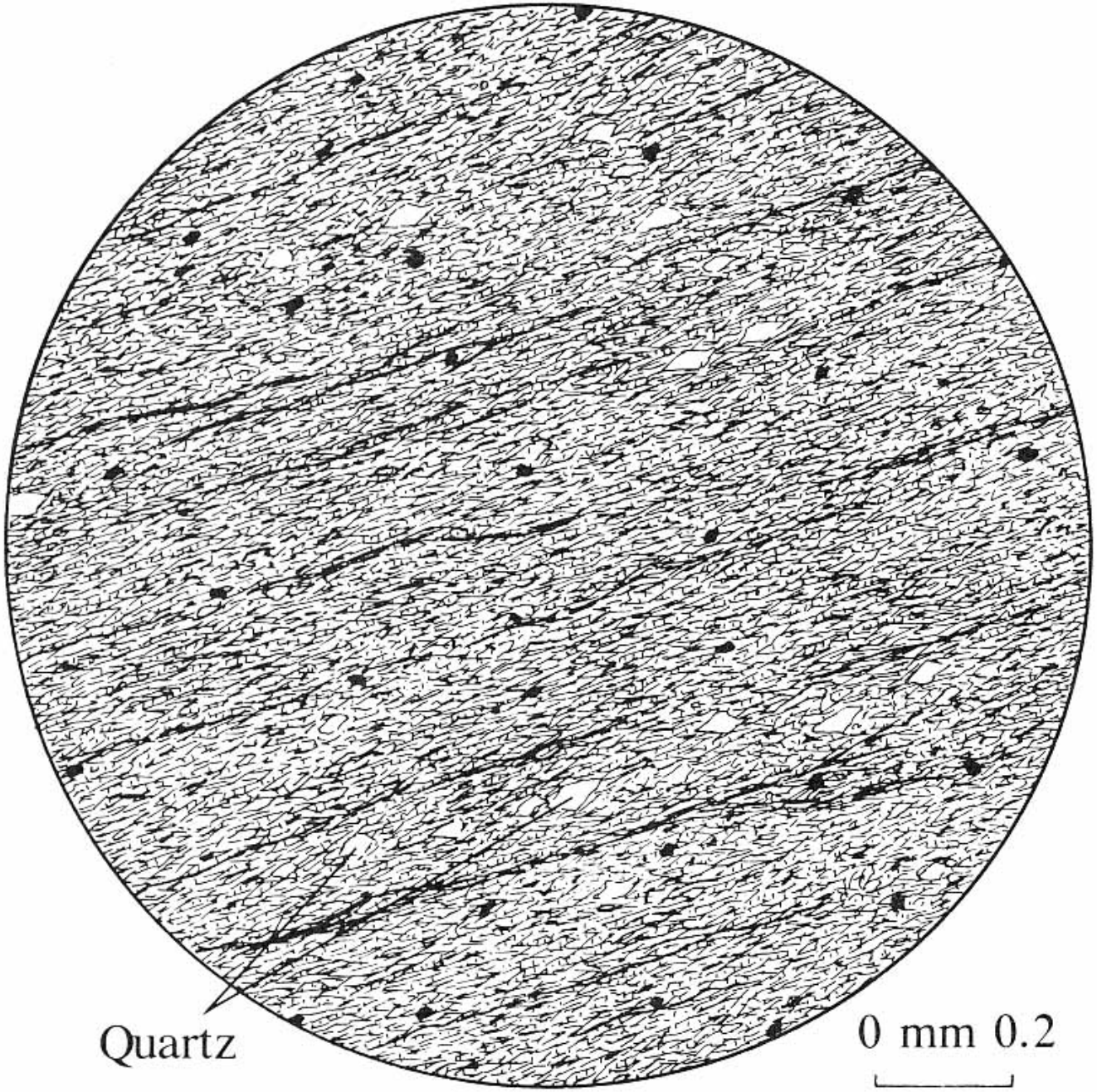


Progressive thermal metamorphism of a diabase (coarse basalt). From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

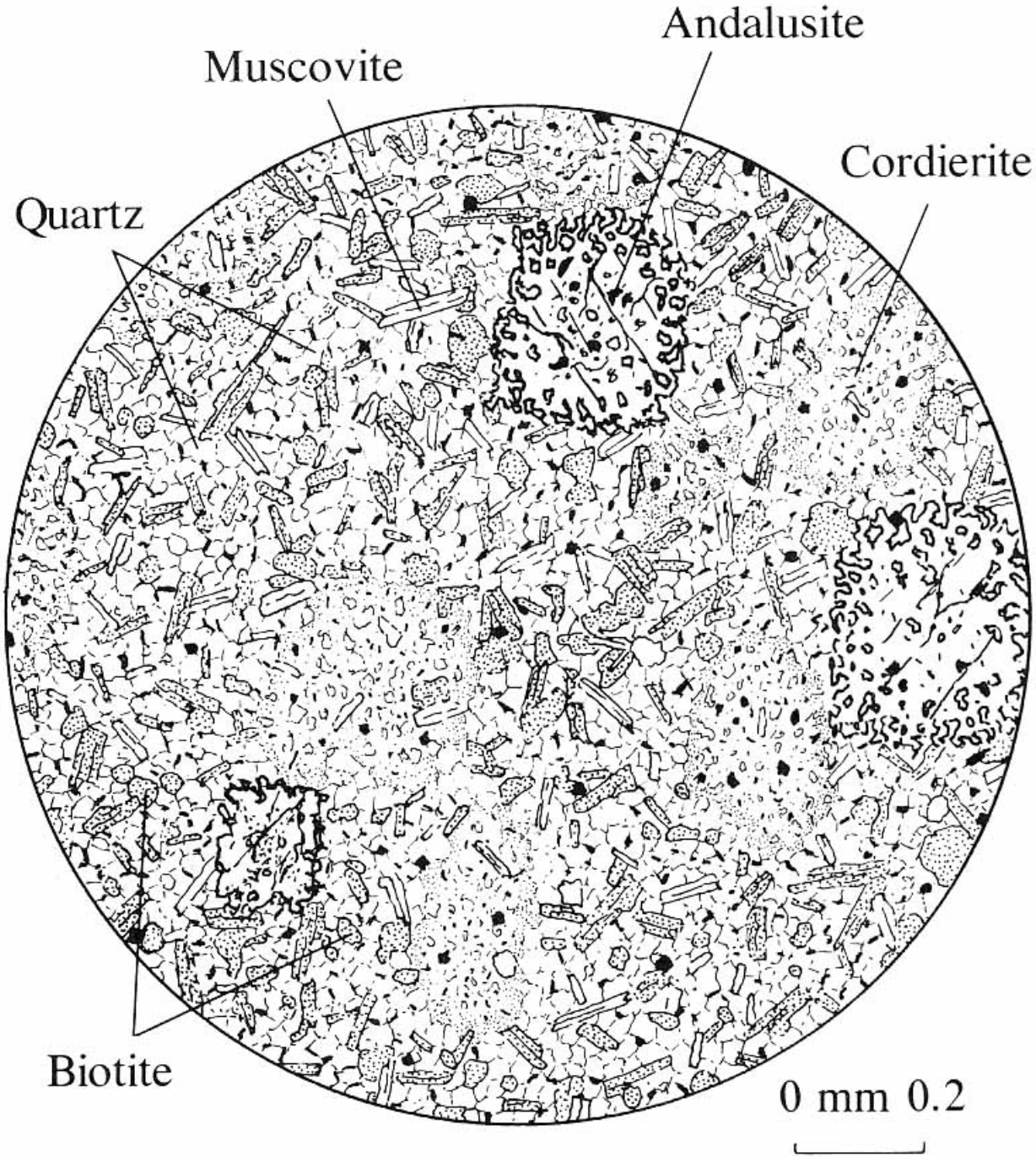
Progressive thermal metamorphism of a diabase (coarse basalt). From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.



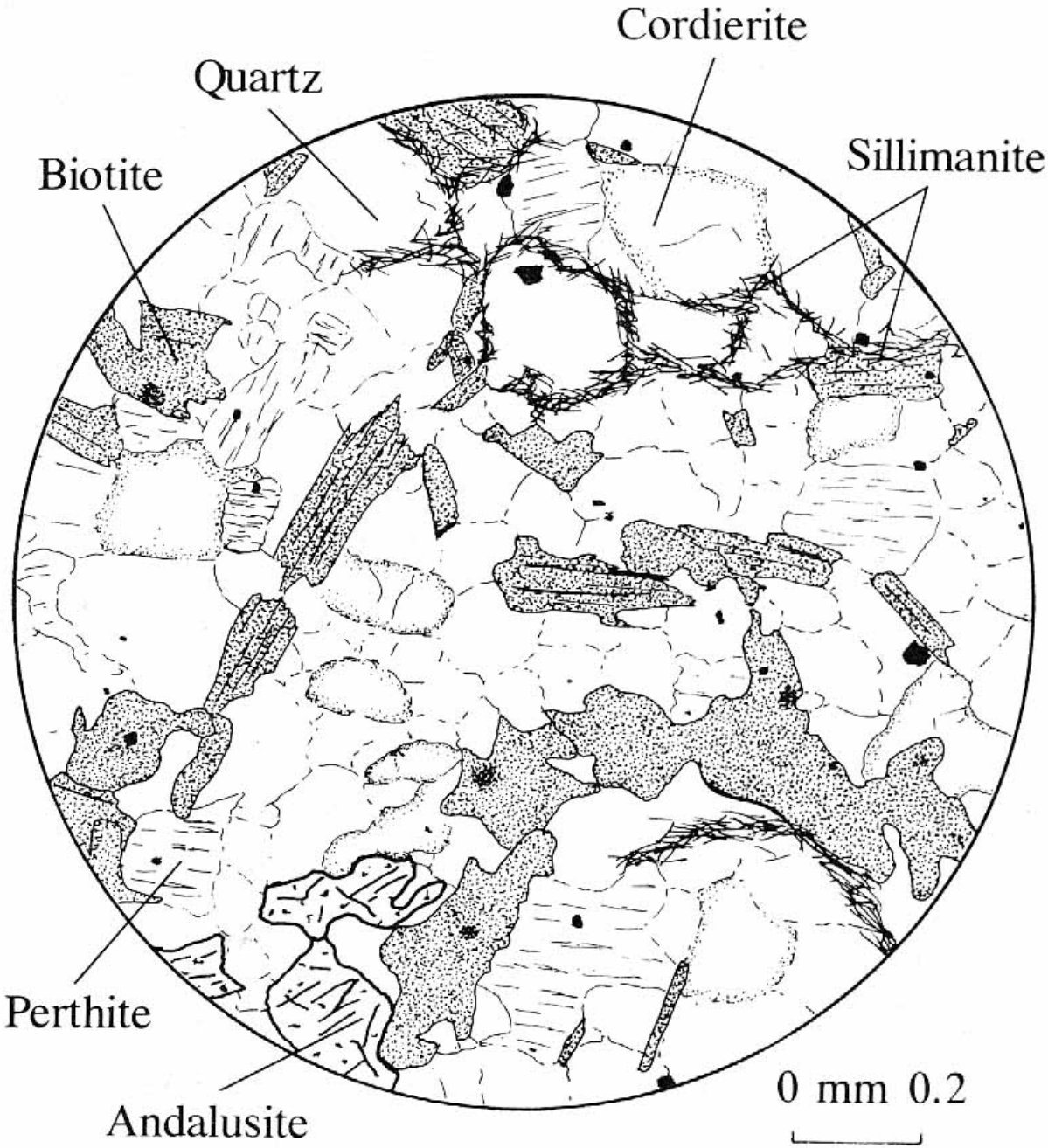




Progressive thermal metamorphism of slate. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.



Progressive thermal metamorphism of slate. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.



Progressive thermal metamorphism of slate. From Best (1982). *Igneous and Metamorphic Petrology*. W. H. Freeman. San Francisco.

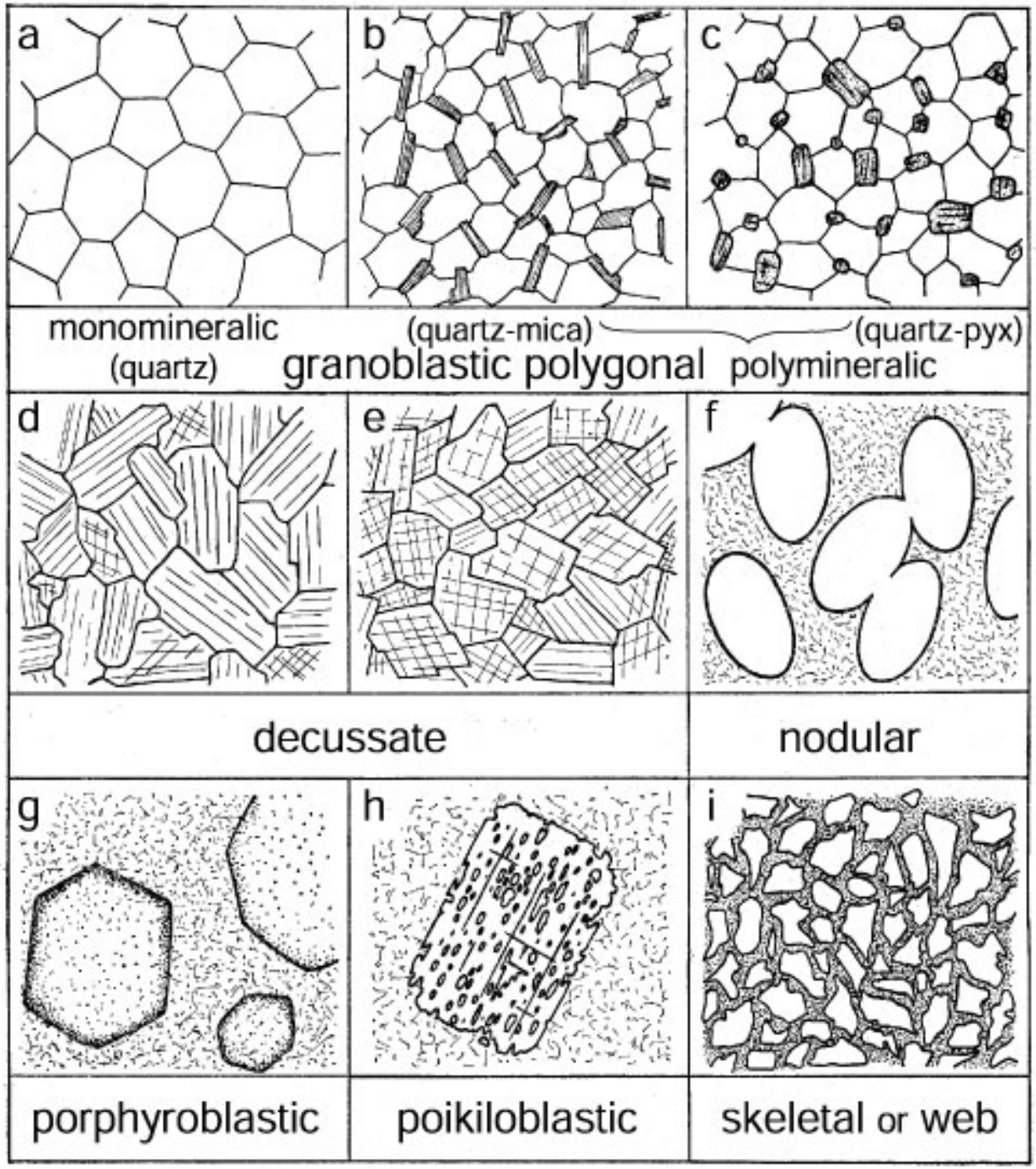
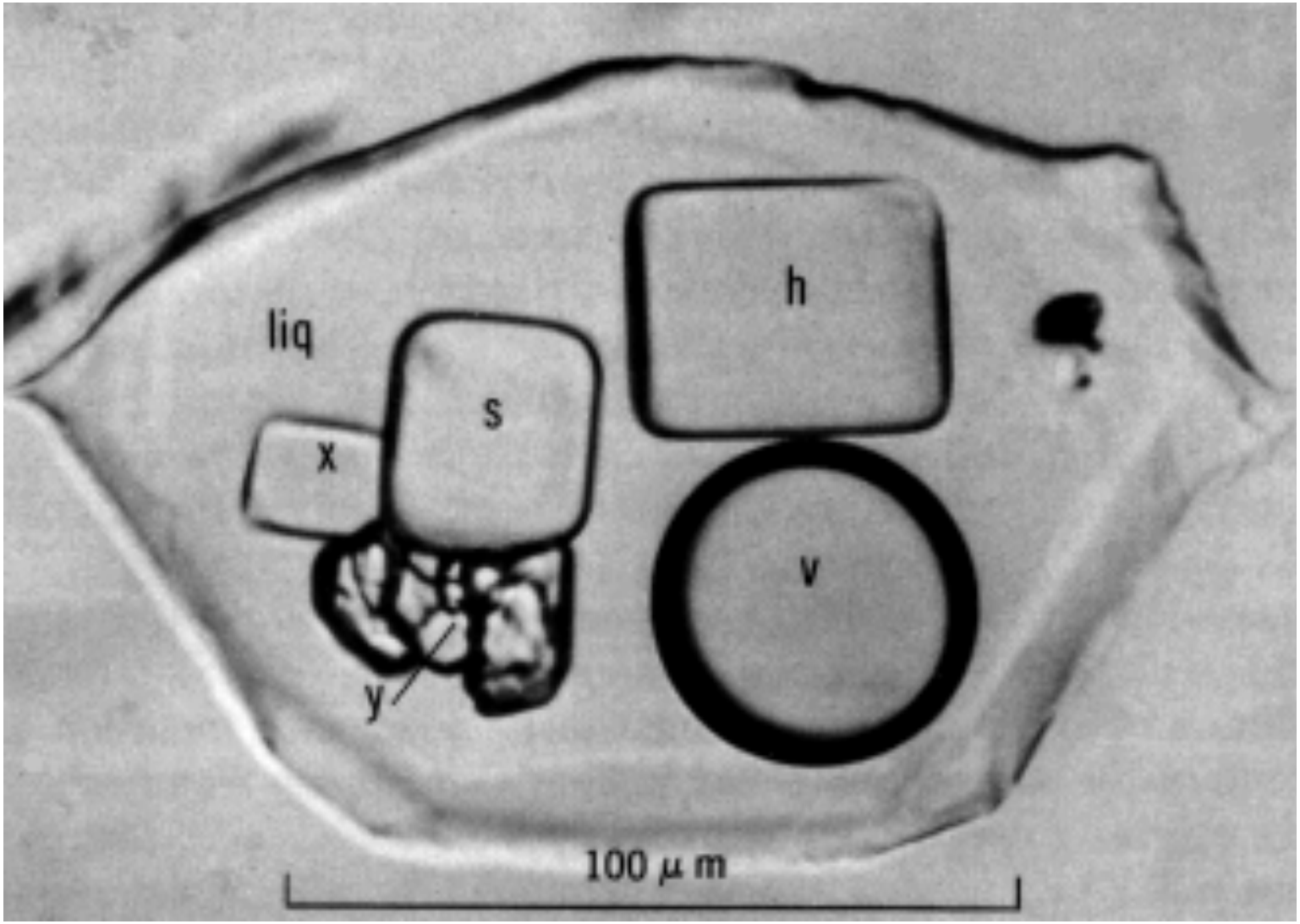
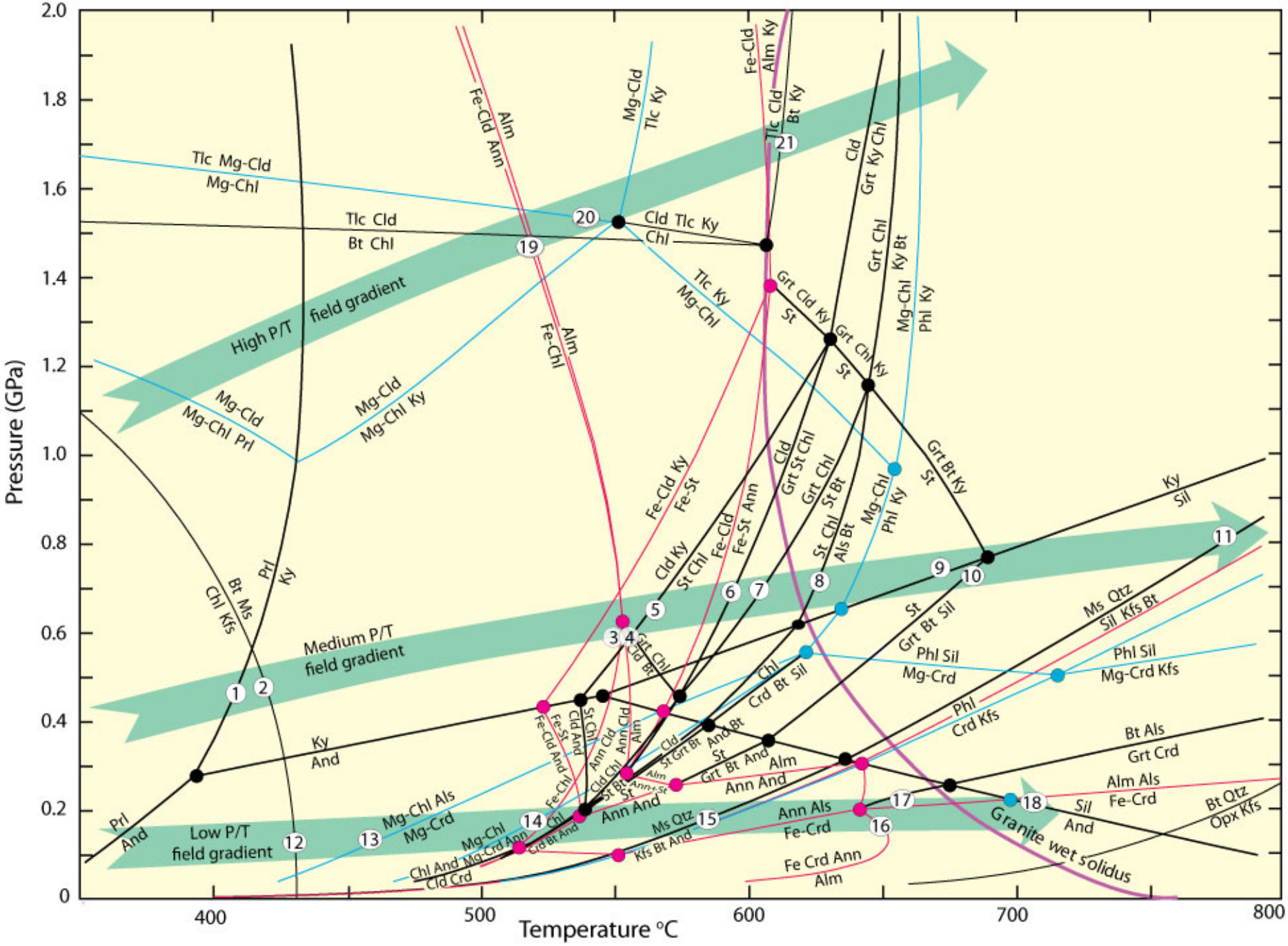


Figure 23.9. Typical textures of contact metamorphism. From Spry (1969) *Metamorphic Textures*. Pergamon. Oxford.

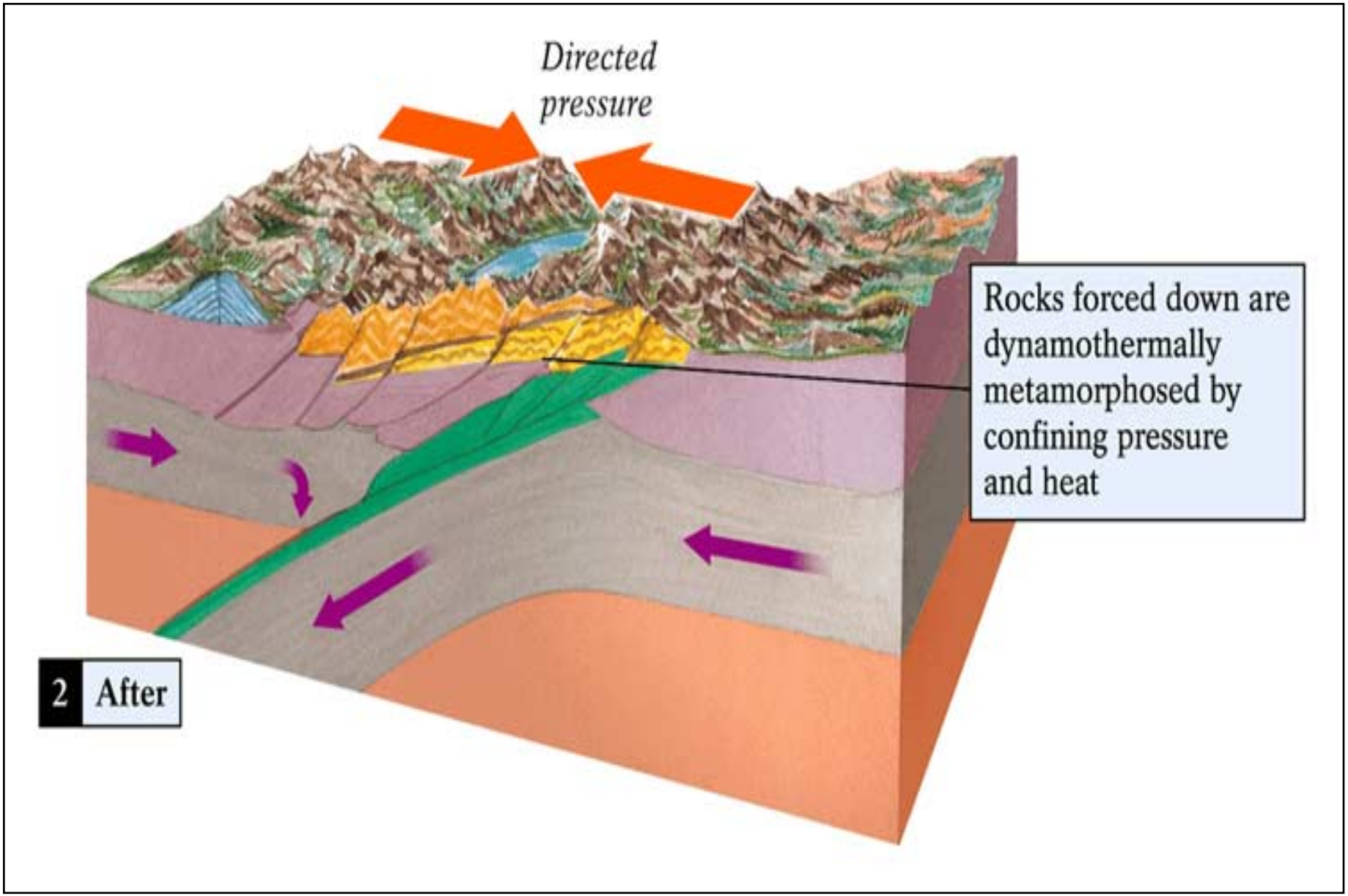
Agentes de Metamorfismo: Fluidos

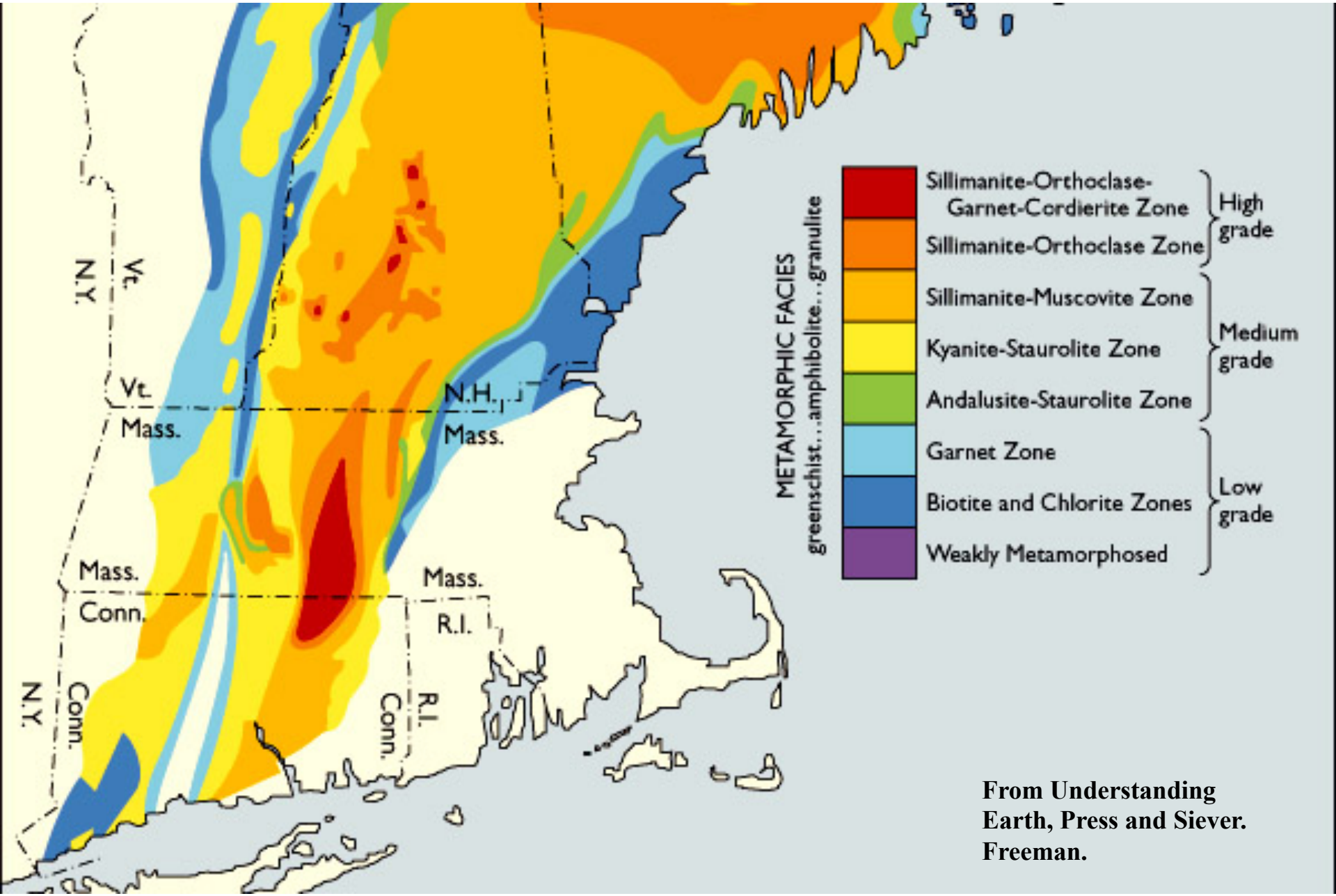


- $P_{fluido} = \Sigma$ pressões parciais de cada componente ($P_{fluido} = p_{H_2O} + p_{CO_2} + \ldots$)
- Frações molares dos componentes deve somar 1.0 ($X_{H_2O} + X_{CO_2} + \ldots = 1.0$)
- $p_{H_2O} = X_{H_2O} \times P_{fluid}$
- Os gradientes de T, P, X_{fluid}, e a composição original da rocha:
- → Zonação das associações minerais metamórficas


Pressure (GPa)
Temperature °C
High P/T field gradient
Medium P/T field gradient
Low P/T field gradient
Granite wet solidus
Tlc Mg-Cld
Mg-Chl
Tlc Cld
Bt Chl
Cld Tlc Ky
Chl
Tlc Ky
Mg-Chl
Mg-Cld
Mg-Chl Prl
Mg-Cld
Mg-Chl Ky
Fe-Cld Ann
Alm
Fe-Chl
Mg-Cld
Tlc Ky
Fe-Cld
Alm Ky
Tlc Cld
Bt Ky
Cld
Grt Ky Chl
Grt Chl
Ky Bt
Mg-Chl
Phl Ky
Grt Cld Ky
St
Grt Chl Ky
St
Grt Bt Ky
St
Fe-Cld Ky
Fe-St
Cld Ky
St Chl
Fe-Cld
Fe-St Ann
Cld
Grt St Chl
Grt Chl
St Bt
St Chl
Als Bt
Mg-Chl
Phl Ky
Ky
Sil
Bt Ms
Chl Kfs
Prl
Ky
Ky
And
Prl
And
Mg-Chl Als
Mg-Crd
Mg-Chl
Chl And Mg-Crd Ann
Cld Crd
Crd Bt And
Ann And
Ann Als
Fe-Crd
Ms Qtz
Kfs Bt And
Fe Crd Ann
Alm
Chl
Crd Bt Sil
Phl Sil
Mg-Crd
St
Grt Bt Sil
Phl
Crd Kfs
Ms Qtz
Sil Kfs Bt
Phl Sil
Mg-Crd Kfs
Bt Als
Grt Crd
Alm Als
Fe-Crd
Sil
And
Bt Qtz
Opx Kfs
Alm
Ann And
Grt Bt And
St
And Bt
Cld
St Grt Bt
Alm
Ann+St
Cld And
Fe-Cld And
Fe-St
Ann Cld
Cld Chl
St Chl
Fe-Chl
Cld Bt
Grt Chl
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
400
500
600
700
800

Metamorfismo Regional ou Orogênico





From Understanding Earth, Press and Siever. Freeman.

Tipos de Protólito

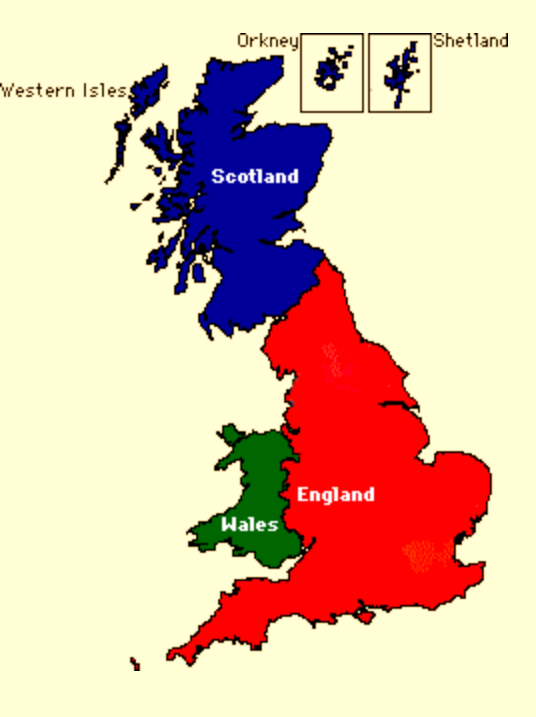
1. Ultramáfico – muito rico em Mg, Fe, Ni, Cr
2. Máfico – rico em Fe, Mg, and Ca
3. Folhelhos (pelítico) – rico em Al, K, Si
4. Carbonatos – rico em Ca, Mg, CO_2
5. Quartzo – SiO_2 e pequena proporção de K, Al.
6. Quartzo-feldspático – rico em Si, Na, K, Al

Metamorfismo Barroviano

- George Barrow (1893, 1912)
- Definido nas SE Highlands da Escócia –

Orogenia Caledoniana ~ 500 Ma

- Protólito: Pelitos
- Contexto tectônico: Colisão
- Fonte de calor: Gradiente geotérmico normal e granitos intrusivos



Área estudada por Barrow

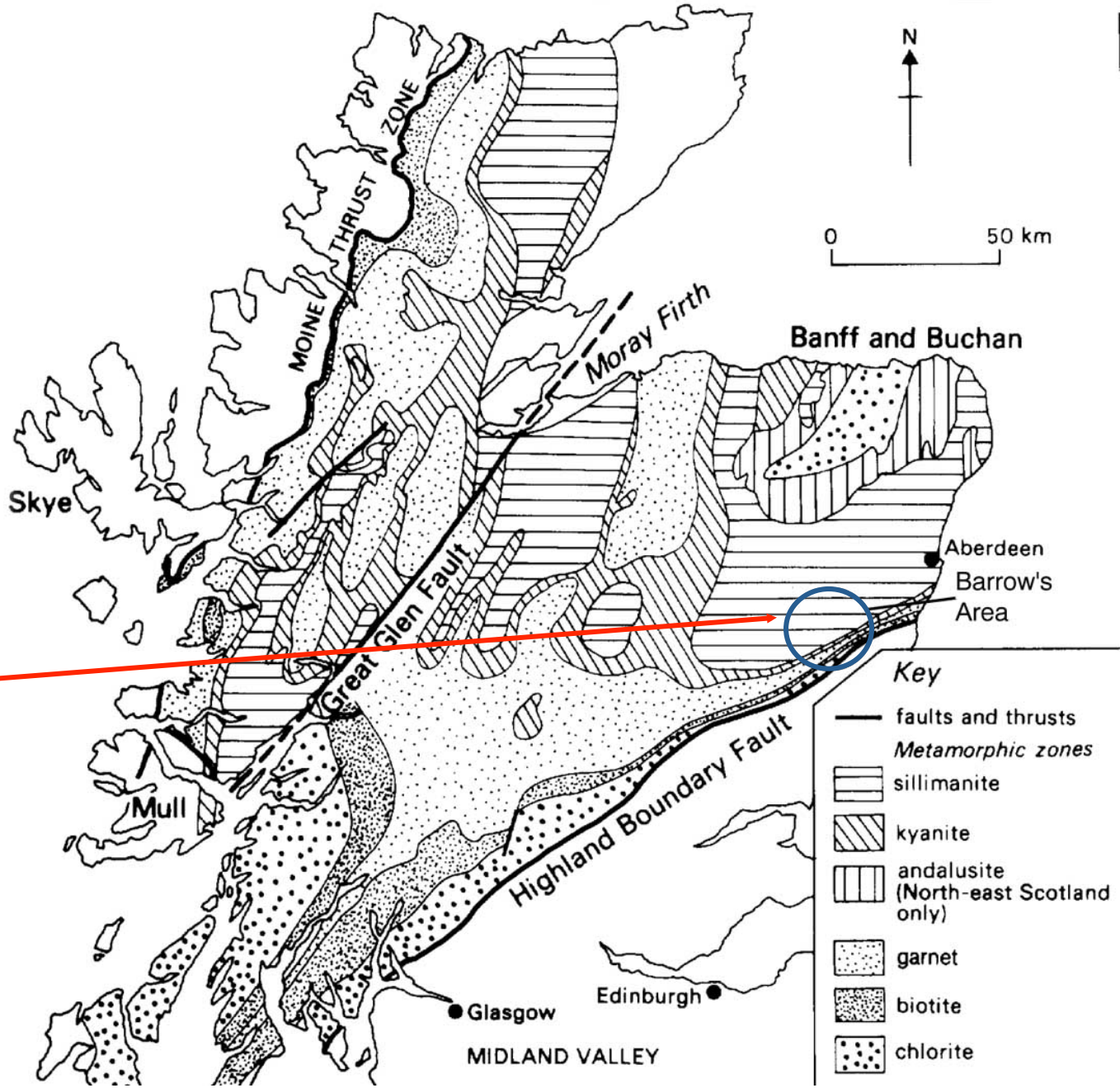


Figure 21.8. Regional metamorphic map of the Scottish Highlands, showing the zones of minerals that develop with increasing metamorphic grade. From Gillen (1982) *Metamorphic Geology. An Introduction to Tectonic and Metamorphic Processes*. George Allen & Unwin. London.

Zonação metamórfica e mineralogia metamórfica típica:

- Clorita. Ardósias ou Filitos, contém clorita, muscovita, quartzo e albita (plagioclásio de Na).
- Biotita. Filitos e Xistos com biotita, clorita, muscovita, quartzoe albita.
- Granada. Xistos com granada vermelha (almandina), biotita, clorita, muscovita, quartzo e albita ou oligoclásio.
- Estaurolita. Xistos com estaurolita, biotita, muscovita, quartzo, granada e plagioclásio. Pode ainda ocorrer clorita.
- Cianita. Xistos com cianita, biotita, muscovita, quartzo, plagioclásio, além de granada e estaurolita.
- Silimanita. Xistos e gnaisses com silimanita, biotita, muscovita, quartzo, plagioclásio, granada, and em alguns casos estaurolita.

Isógrada = linha que separa as zonas metamórficas (campos com grau metamórfico constante)

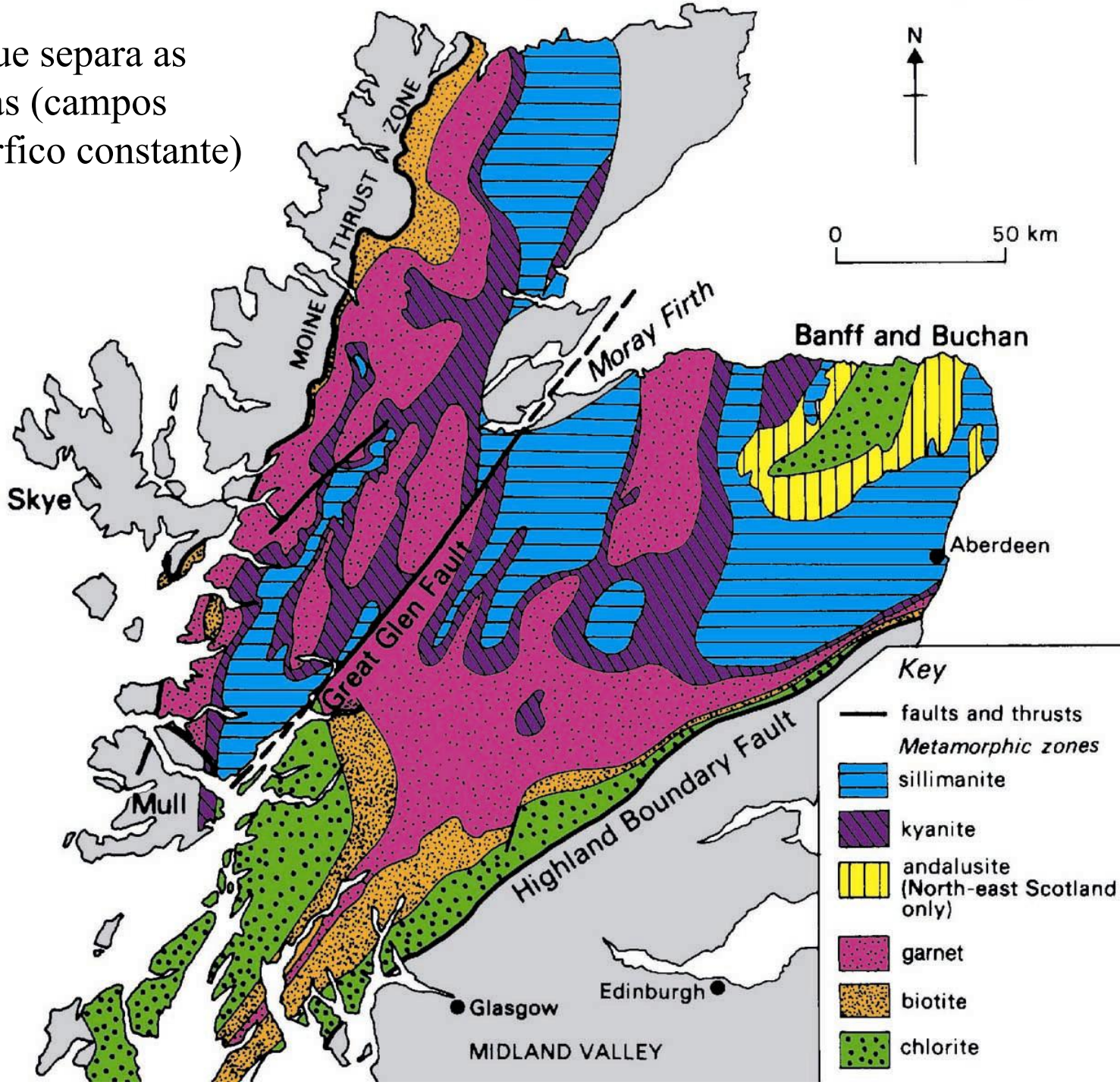


Figure 21.8. Regional metamorphic map of the Scottish Highlands, showing the zones of minerals that develop with increasing metamorphic grade. From Gillen (1982) *Metamorphic Geology. An Introduction to Tectonic and Metamorphic Processes*. George Allen & Unwin. London.

Isógradas e Zonas Metamórficas

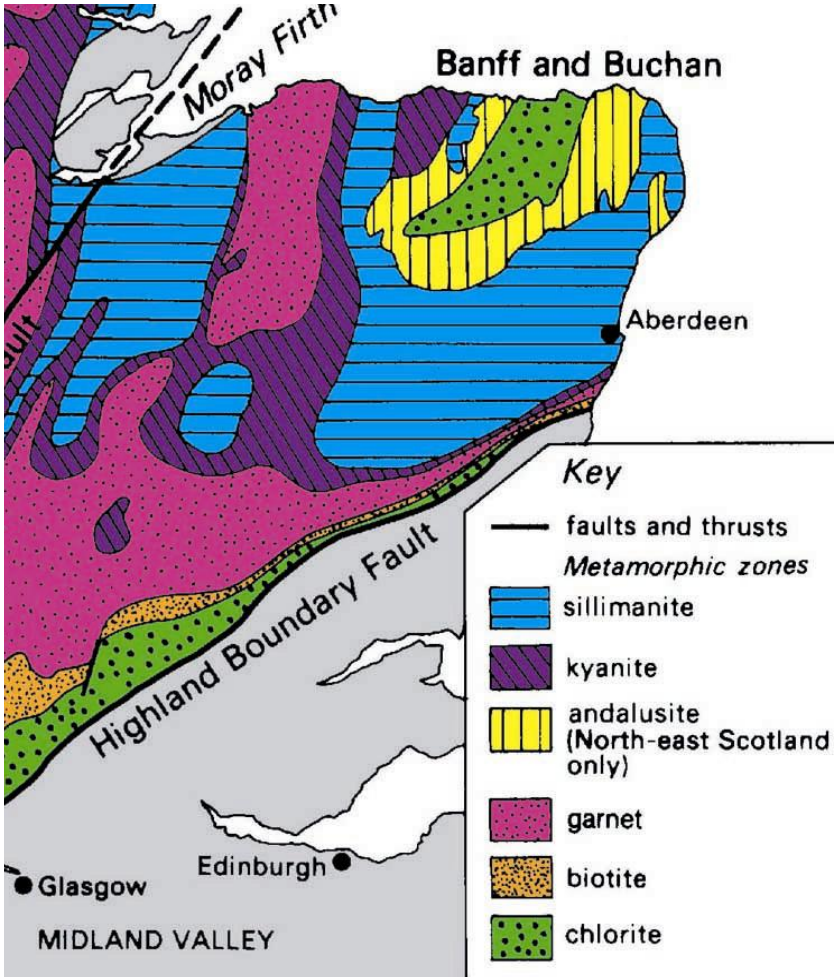
- Uma isógrada representa a primeira aparição de um mineral índice à medida em que o grau metamórfico aumenta;
- Quando cruzamos uma isógrada, por exemplo a da estaurolita, entramos na zona metamórfica correspondente, no caso a zona da estaurolita;
- As zonas metamórficas tem o mesmo nome da isógrada que define a sua base, o seu limite de menor temperatura e pressão;
- Como a isógrada é definida como a primeira ocorrência de um mineral índice, ele pode ainda ser encontrado mais adiante, mesmo em outras zonas metamórficas.

Um exemplo de variações nas Zonas Metamórficas em escala regional pode ser encontrado no Distrito de Banff and Buchan district, ao norte da área originalmente estudada por Barrow

As rochas originais (protólitos) são as mesmas, rochas pelíticas, mas a sequência de zonas metamórficas é diferente:

- Clorita
- Biotita
- Cordierita
- Andalusita
- Sillimanite

Por quê ?



O campo de estabilidade da Andalusita está em P < 0.37 GPa (~ 10 km), enquanto o da Cianita → Silimanita está em P > 0.37 GPa.

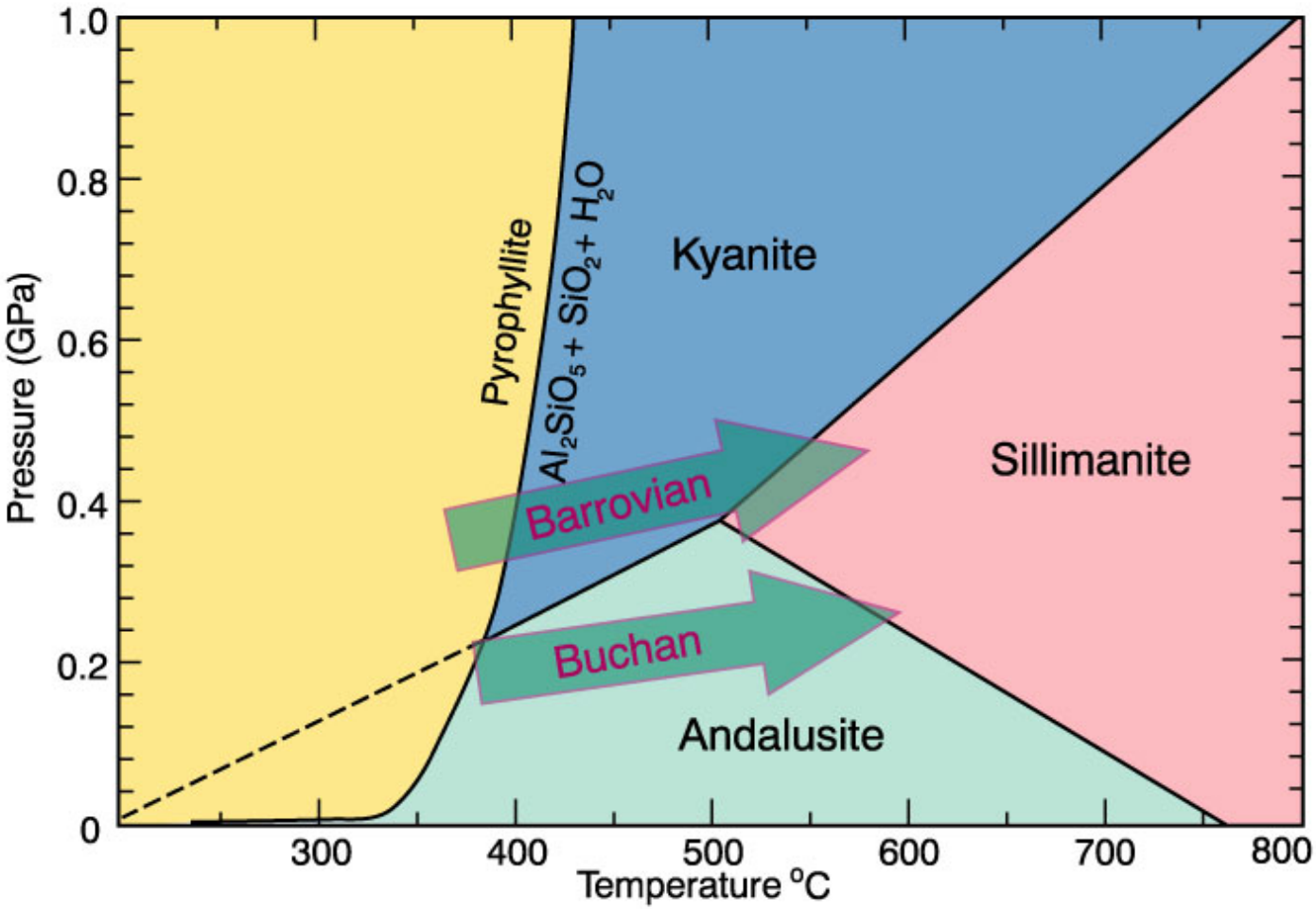
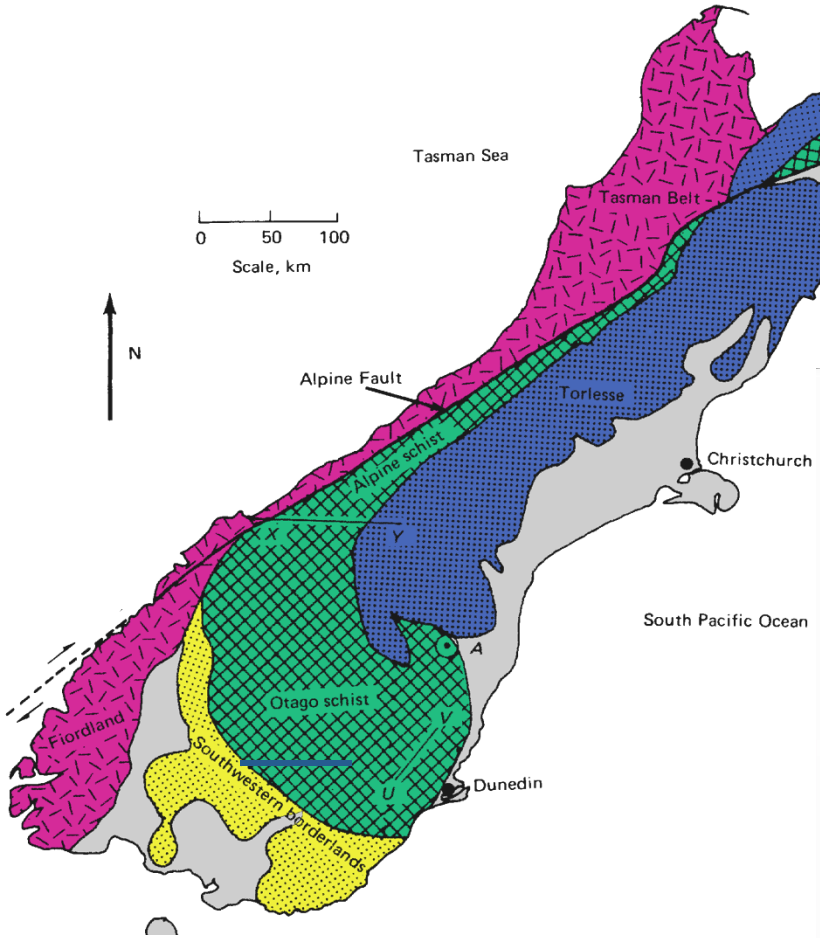


Figure 21.9. The P-T phase diagram for the system Al_2SiO_5 showing the stability fields for the three polymorphs andalusite, kyanite, and sillimanite. Also shown is the hydration of Al_2SiO_5 to pyrophyllite, which limits the occurrence of an Al_2SiO_5 polymorph at low grades in the presence of excess silica and water. The diagram was calculated using the program TWQ (Berman, 1988, 1990, 1991).

Metamorfismo Regional de Otago, Nova Zelândia

- Definido na porção Oeste da Ilha Sul da Nova Zelândia Deformação do Cretáceo ~100 Ma
- Protólito: Grauvacas, tufos e vulcânicas
- Contexto tectônico: Colisão
- Fonte de calor: gradiente geotérmico normal



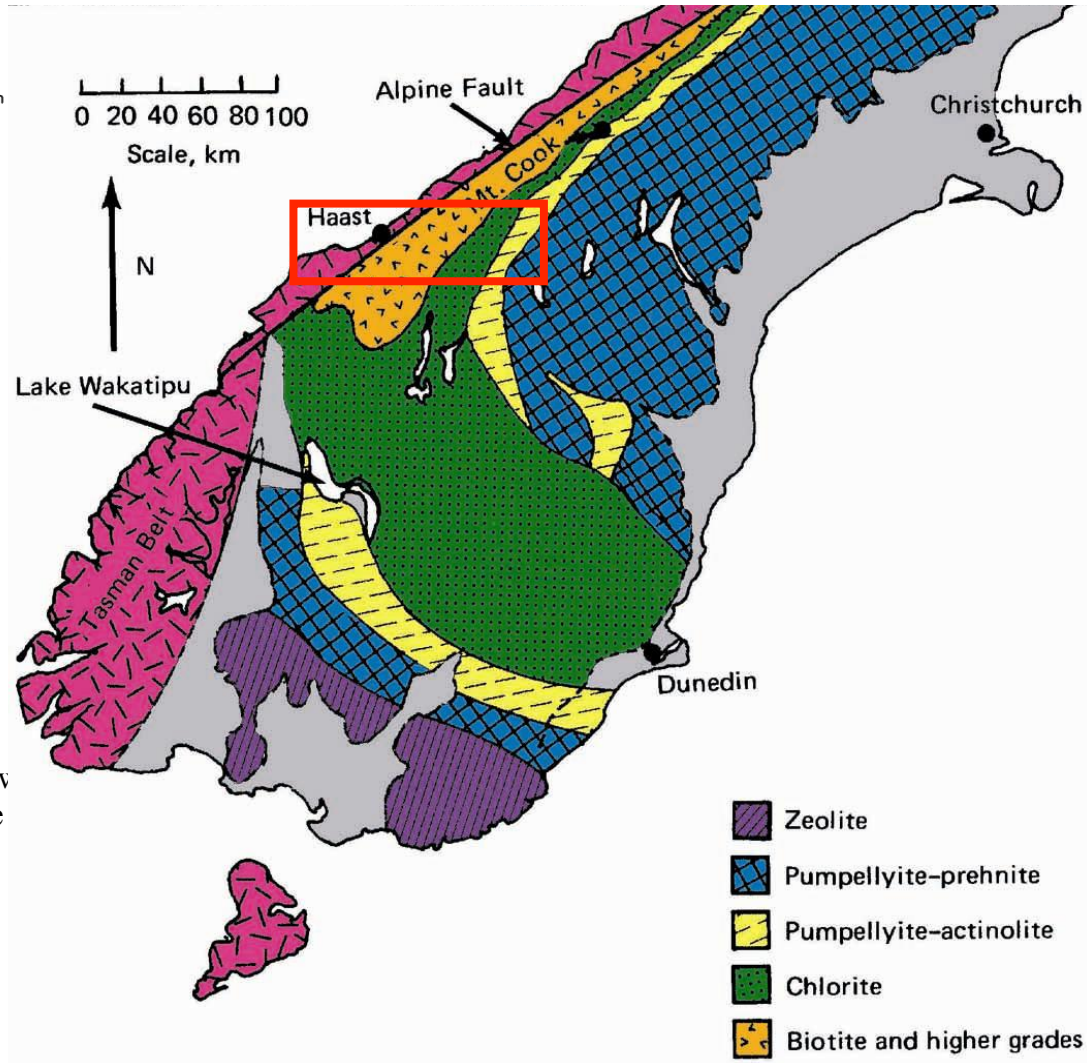
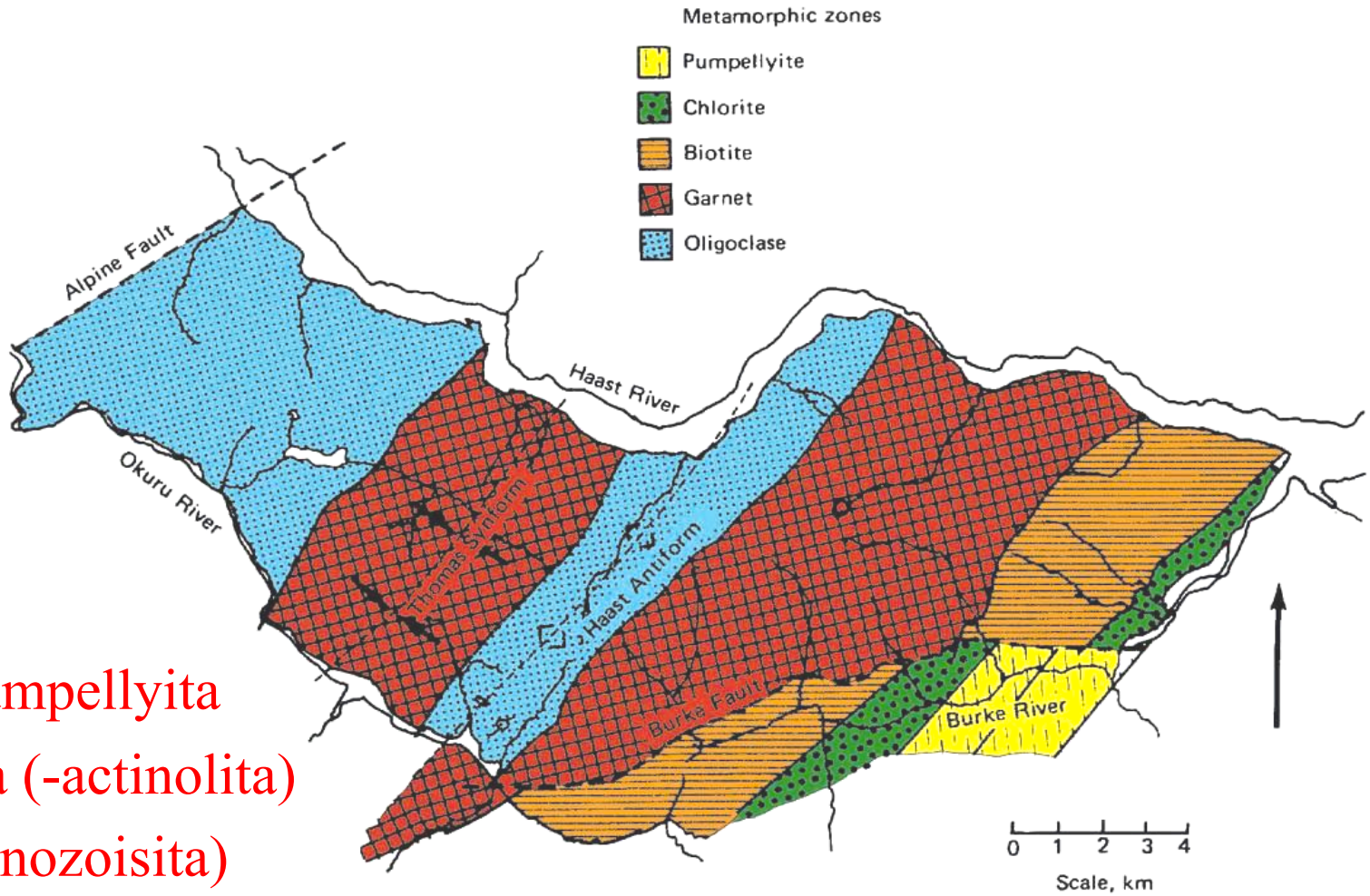


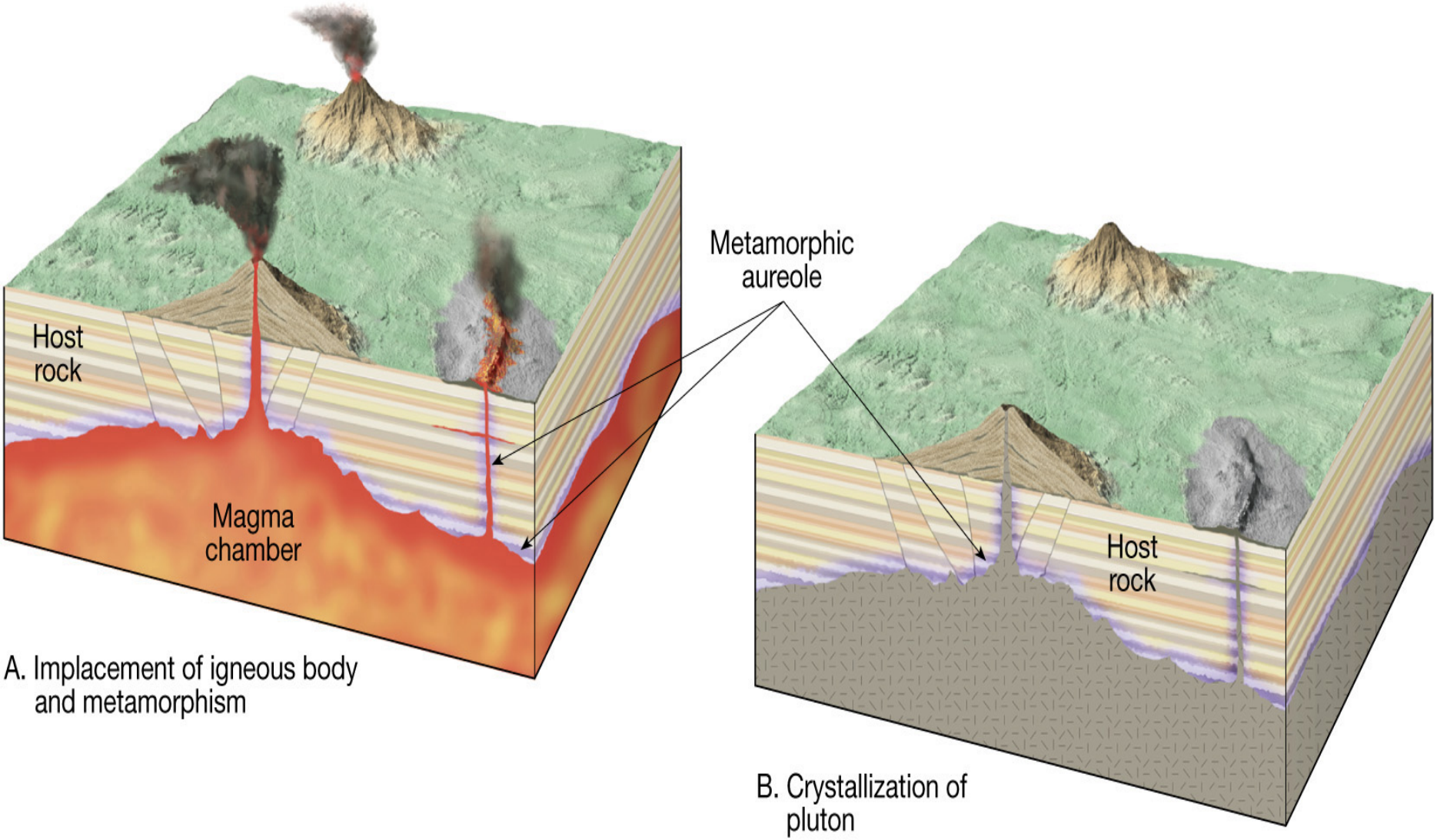
Figure 21.10. Geologic sketch map of the South Island of New Zealand showing the Mesozoic metamorphic rocks east of the older Tasman Belt and the Alpine Fault. The Torlese Group is metamorphosed predominantly in the prehnite-pumpellyite zone, and the Otago Schist in higher grade zones. X-Y is the Haast River Section of Figure 21-11. From Turner (1981) *Metamorphic Petrology: Mineralogical, Field, and Tectonic Aspects*. McGraw-Hill.



Isógradas:

1) Zeólita
2) Prehnita-Pumpellyita
3) Pumpellyita (-actinolita)
4) Clorita (-clinozoisita)
5) Biotita
6) Almandina (garnet)
7) Oligoclásio (A Albite observada em zonas de grau metamórfico mais baixo é substituída por plagioclásio mais rico em Ca)

Metamorfismo de contato

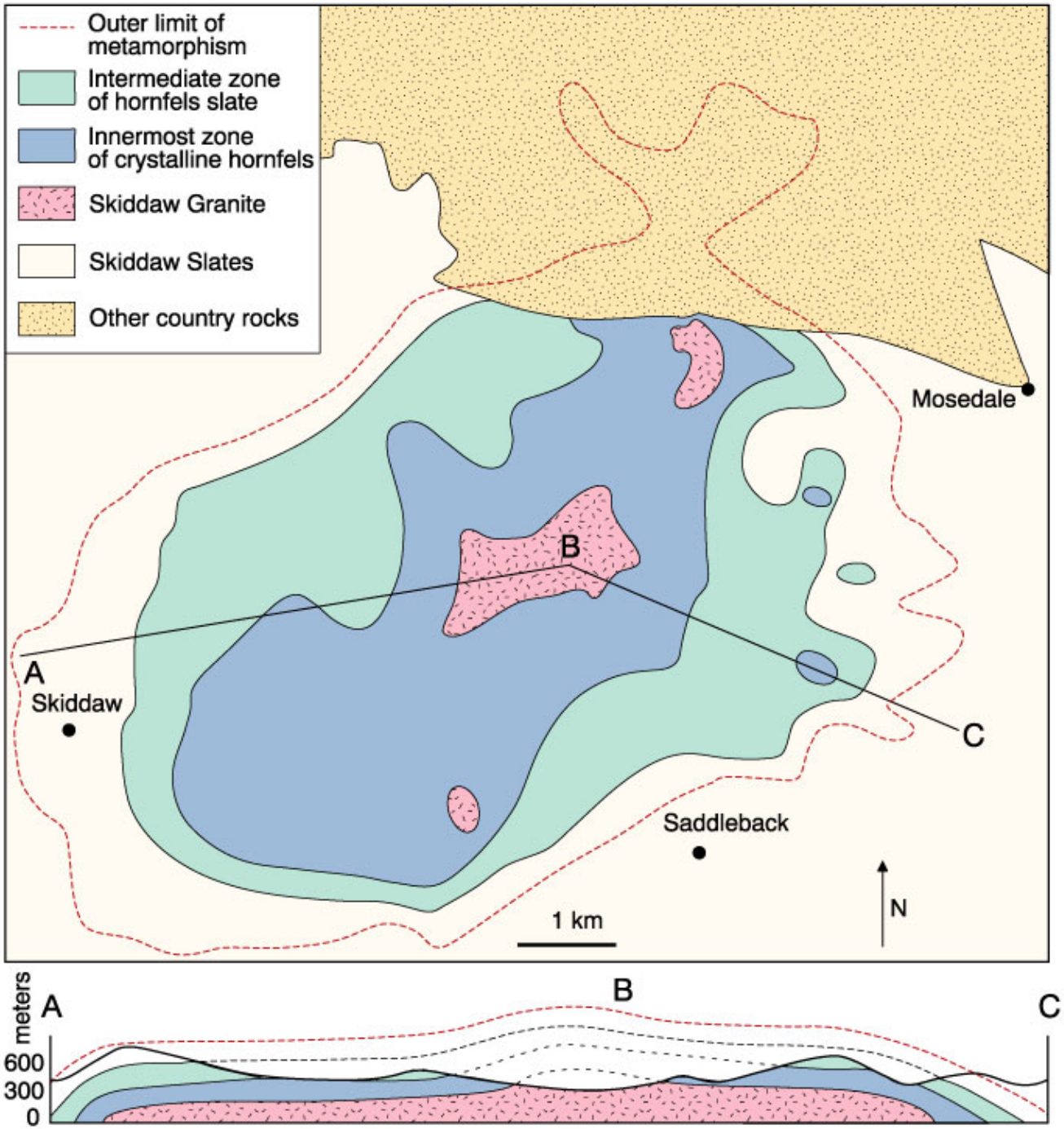


A. Implacement of igneous body and metamorphism

B. Crystallization of pluton

Metamorfismo de Contato (Skiddaw Aureole, UK)

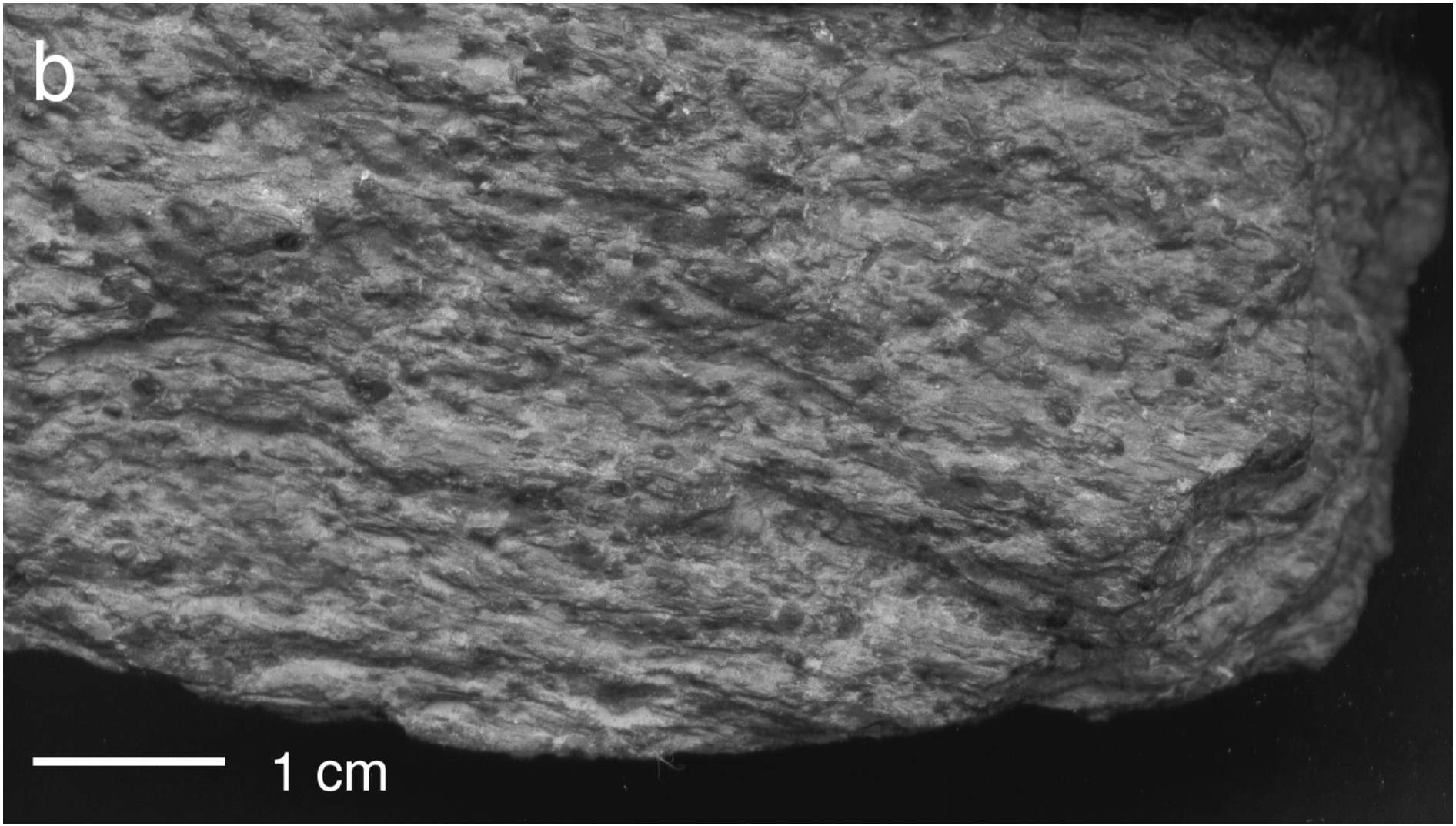
- Definido nas auréolas de metamorfismo de intrusões graníticas em Skiddaw, UK)
- Protólito: Filitos que já haviam sofrido metamorfismo regional
- Contexto tectônico: sem tectonismo importante
- Fonte de calor: forte gradiente geotérmico devido à proximidade de intrusões graníticas



A auréola metamórfica do Granito Skiddaw é dividida em três zonas, com base nas texturas das rochas:

- Filitos inalterados
- Zona externa, com filitos “pintados”
- Zona intermediária, com filitos a Andalusita
- Zona interna, com hornfels (rochas

- Zona externa: filitos ‘pintados’ contendo biotita + muscovita + cordierita + quartzo. A estrutura foliada é bastante visível, mas algumas ‘pintas’ indicando novos minerais diferencia essas rochas das rochas originais.



- Zona intermediária: filitos recristalizados contendo biotita + muscovita + cordierita + andalusita + quartzo

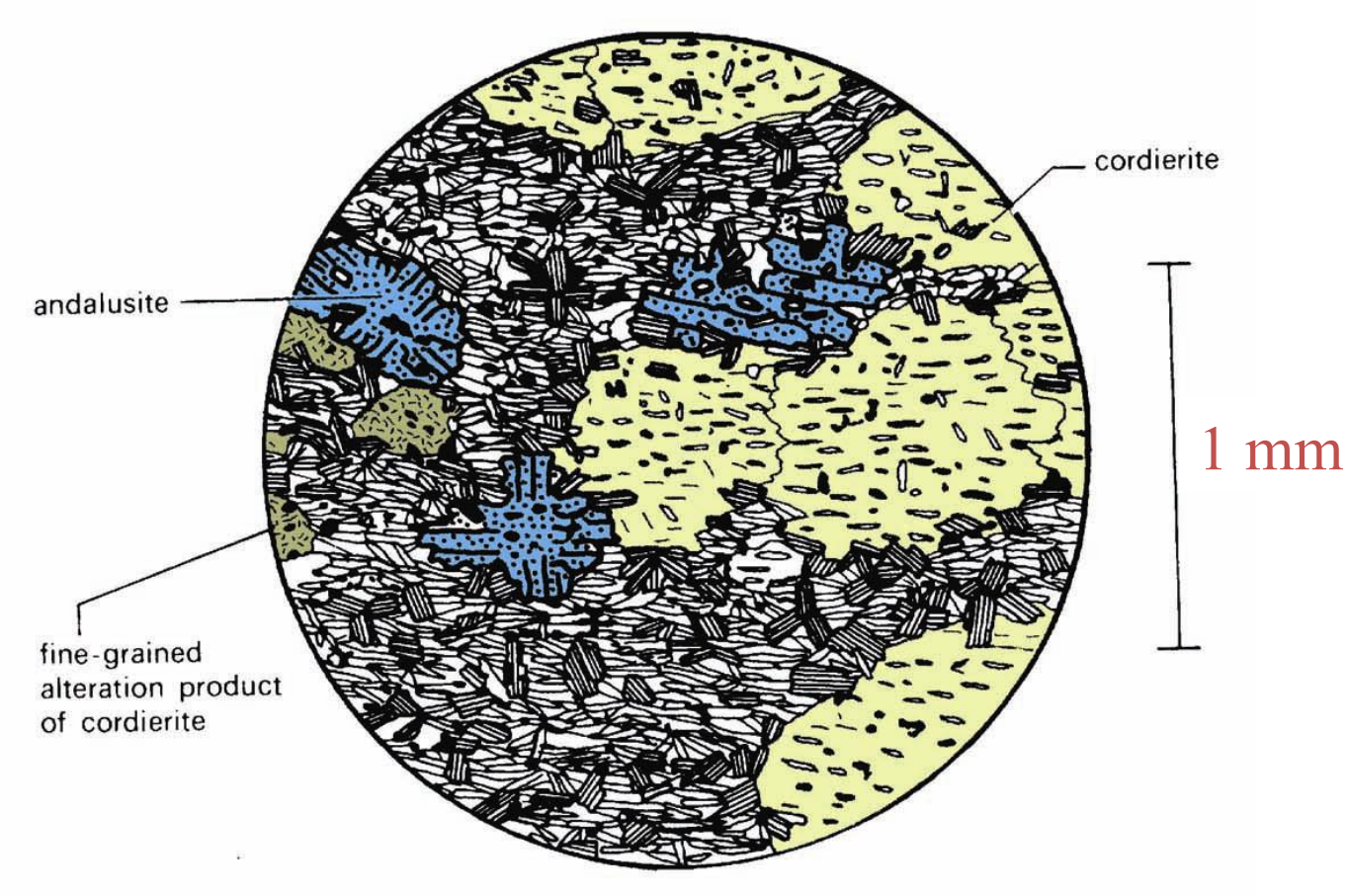


Figure 21.15. Cordierite-andalusite slate from the middle zone of the Skidda aureole. From Mason (197 *Petrology of the Metamorphic Rocks*. Geor Allen & Unwin. London.

- Zona interna (hornfels): filitos bastante recristalizados contendo biotita + muscovita + cordierita + andalusita + quartzo. Toda a estrutura da rocha original foi apagada.

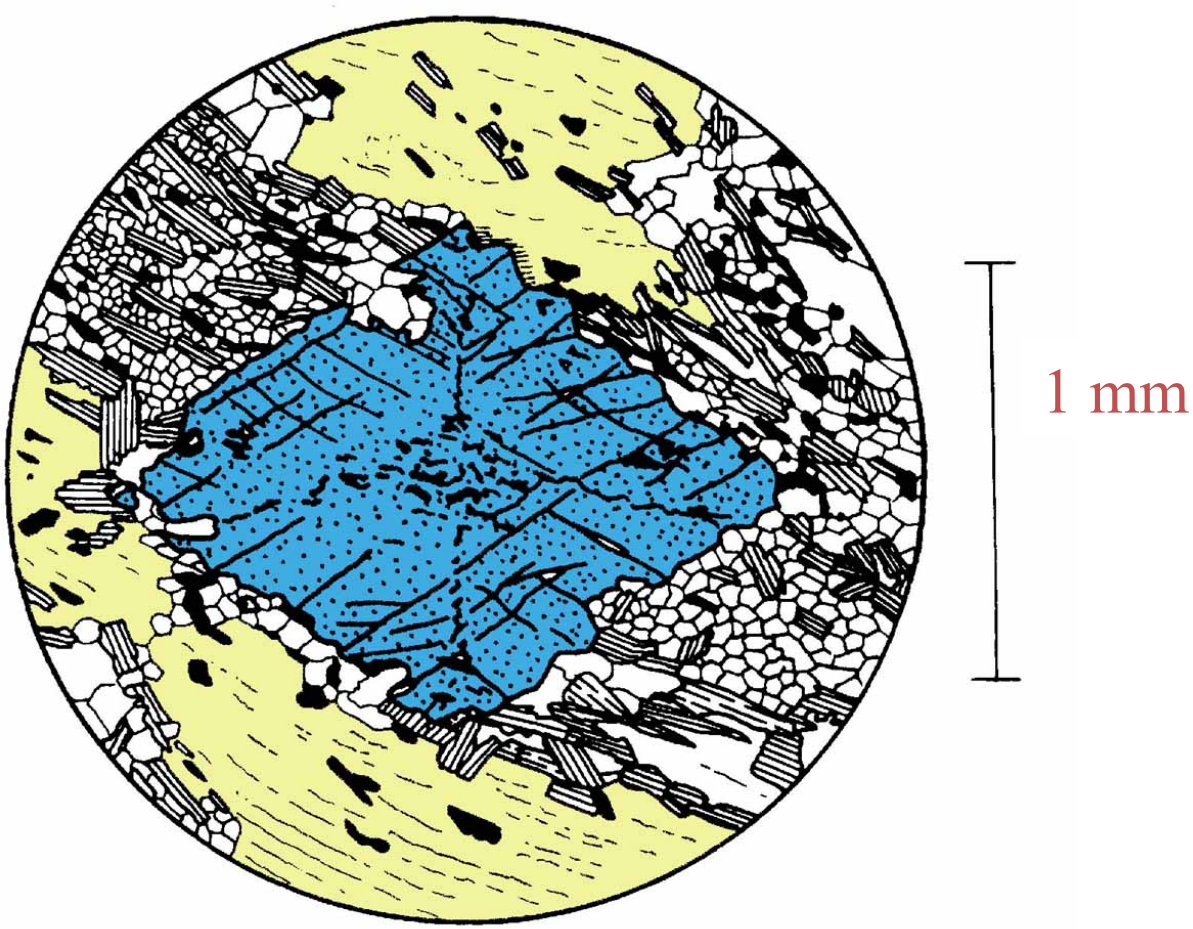
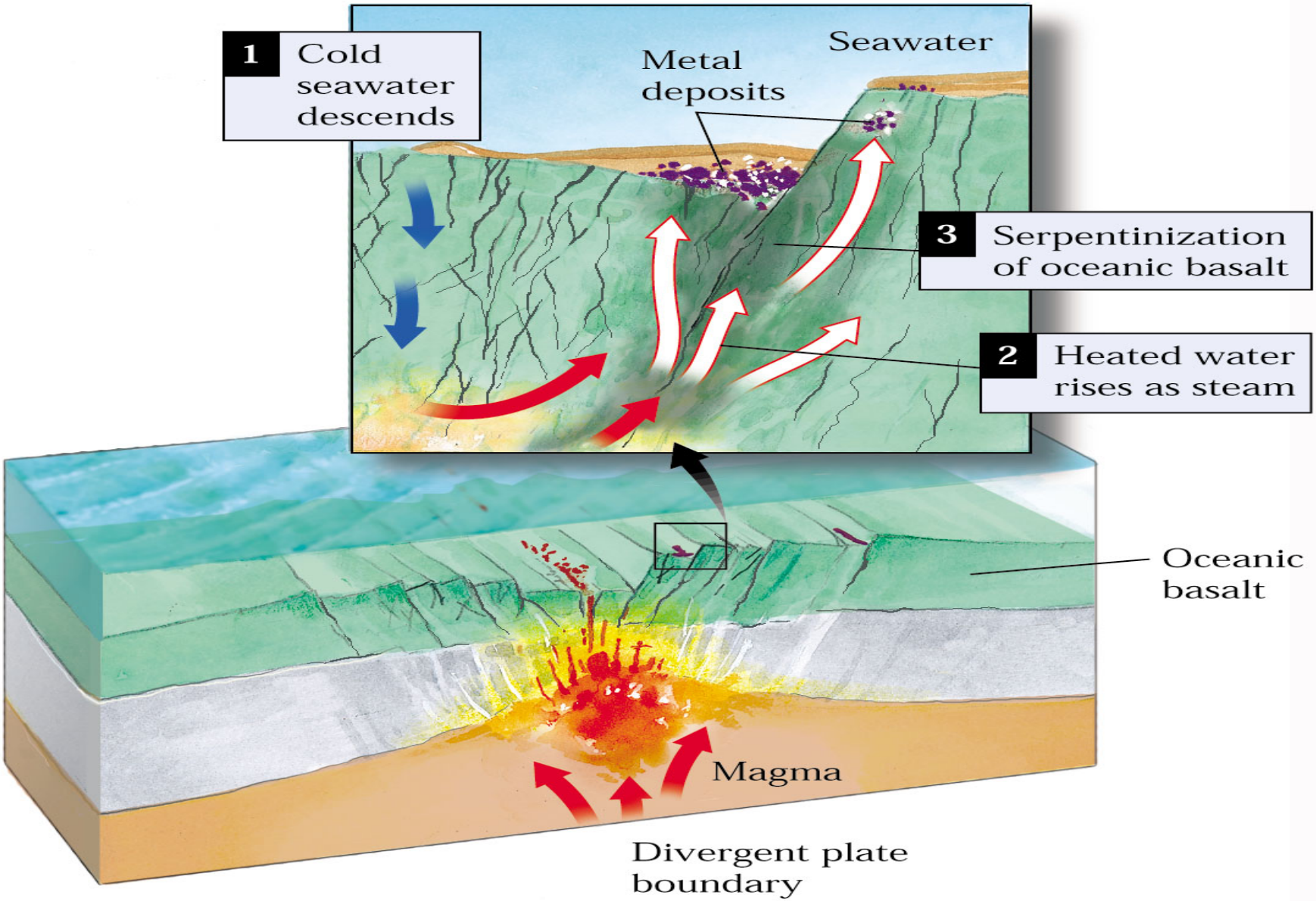


Figure 21.16. Andalusite-cordierite schist from the inner zone of the Skiddaw aureole. Note the chiastolite cross in andalusite (see also Figure 22-49). From Mason (1978) *Petrology of the Metamorphic Rocks*. George Allen & Unwin. London.

Metamorfismo do fundo oceânico



Circulation of hot water in cracks at mid-ocean ridge dissolves metals (Copper, Tin, Iron, Zinc, Lead, Barium) which are re-precipitated as sulfide ores. Hydrothermal waters are capable of metamorphism.

Primeiras etapas da transformação metamórfica de rochas ultramáficas: via de regra, hidratação (com ou sem carbonatação adicional) em baixo a médio grau – formação de serpentinas, talco, brucita, magnesita / dolomita, tremolita, etc.

Exemplos: rochas ultramáficas do manto litosférico e de complexos cumuláticos da crosta oceânica, em ofiolitos e peridotitos alpinos, ou komatiítos em *greenstone belts* (fácies sub-xisto verde a xisto verde).

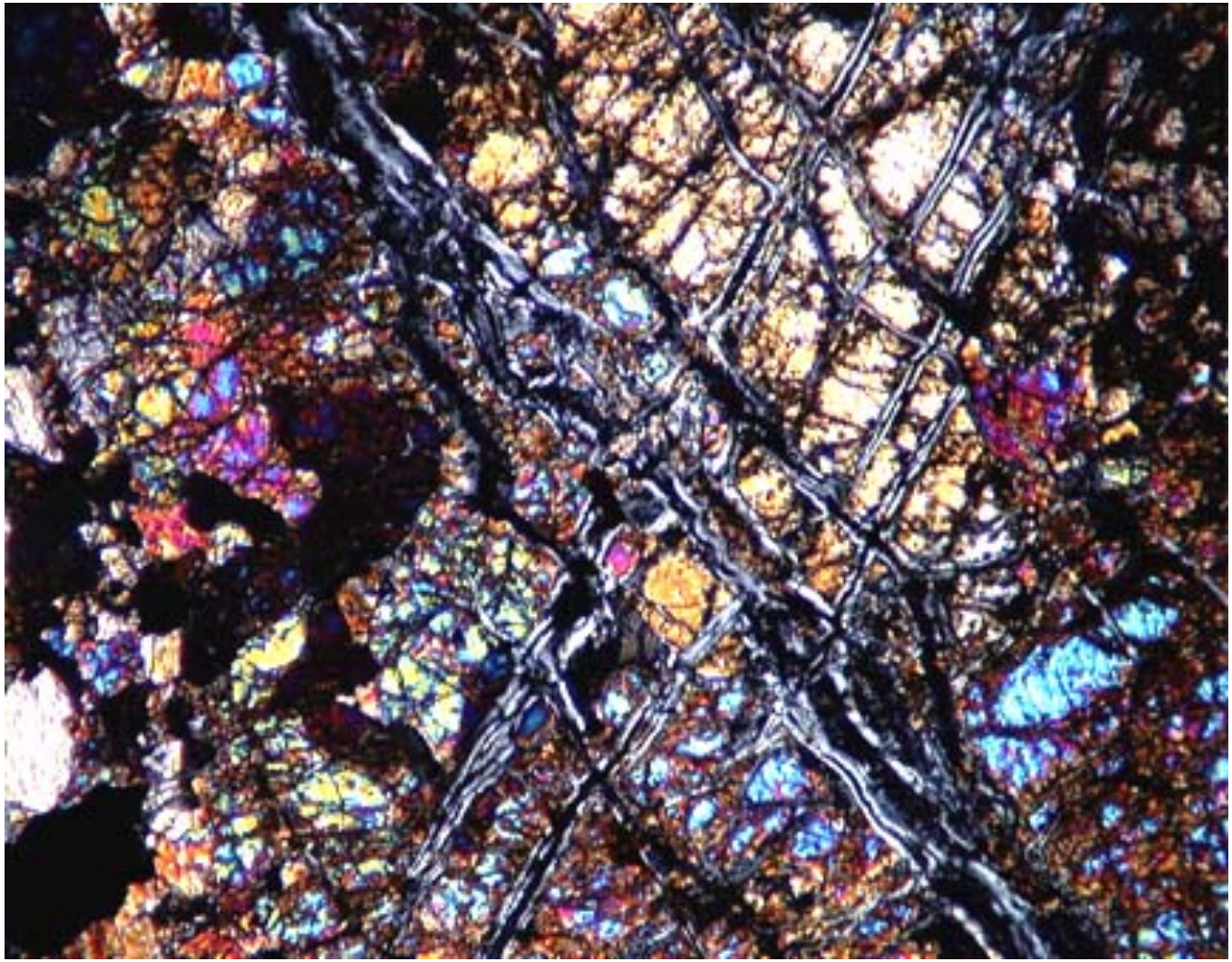
Serpentinização: pode ocorrer em sistema parcialmente fechado, com acesso apenas de fluidos aquosos, ou em sistema aberto (remoção de Na_2O, CaO, Al_2O_3)

Atinge preferencialmente os minerais com relação Mg:Si mais elevada: olivina e ortopiroxênio.

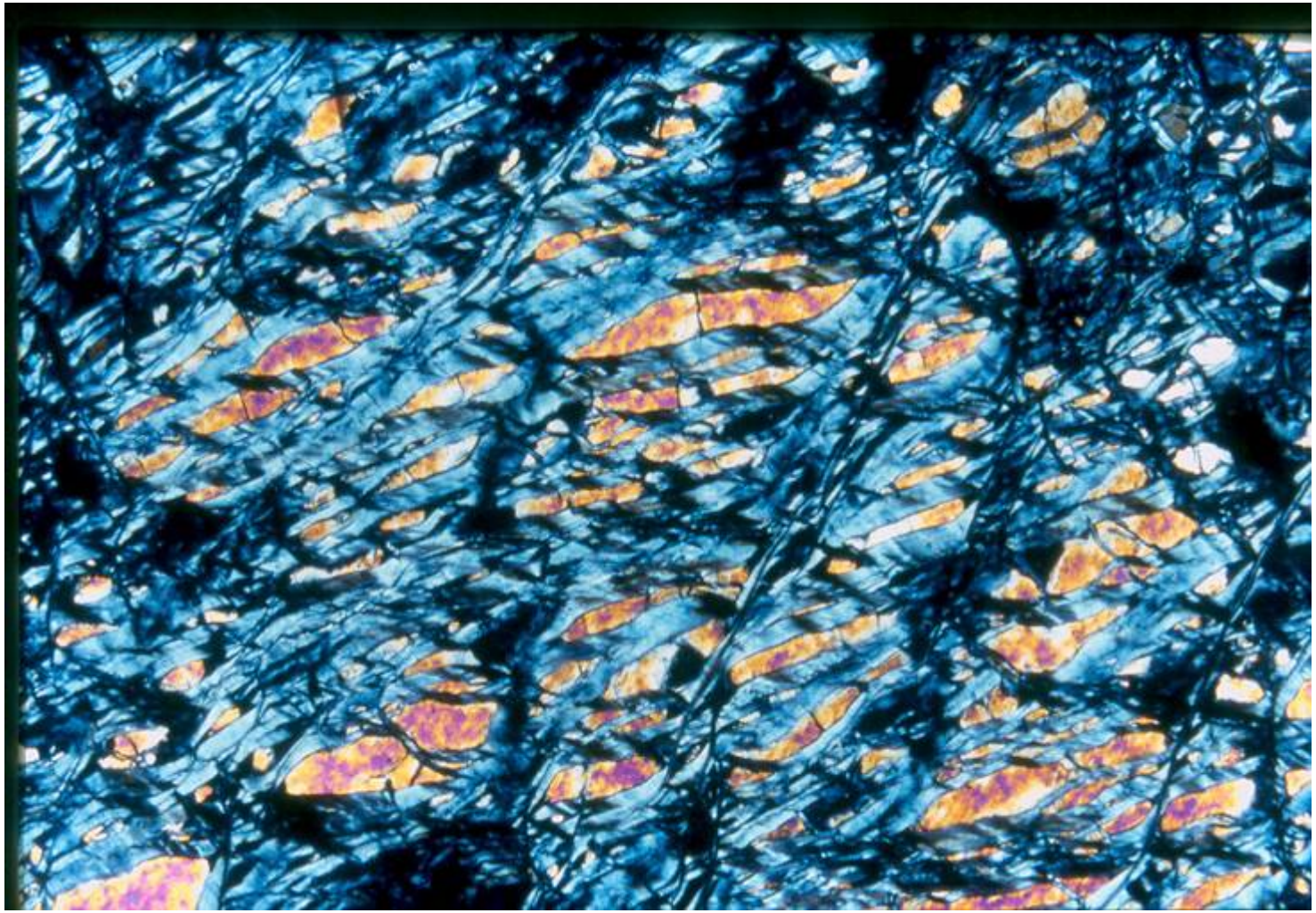
Serpentinitos: rochas metaultramáficas mais abundantes na crosta – geralmente, ponto de partida para o metamorfismo progressivo.

Serpentinito com veios de quartzo (Liberdade, MG)

Serpentinização ao longo de fraturas

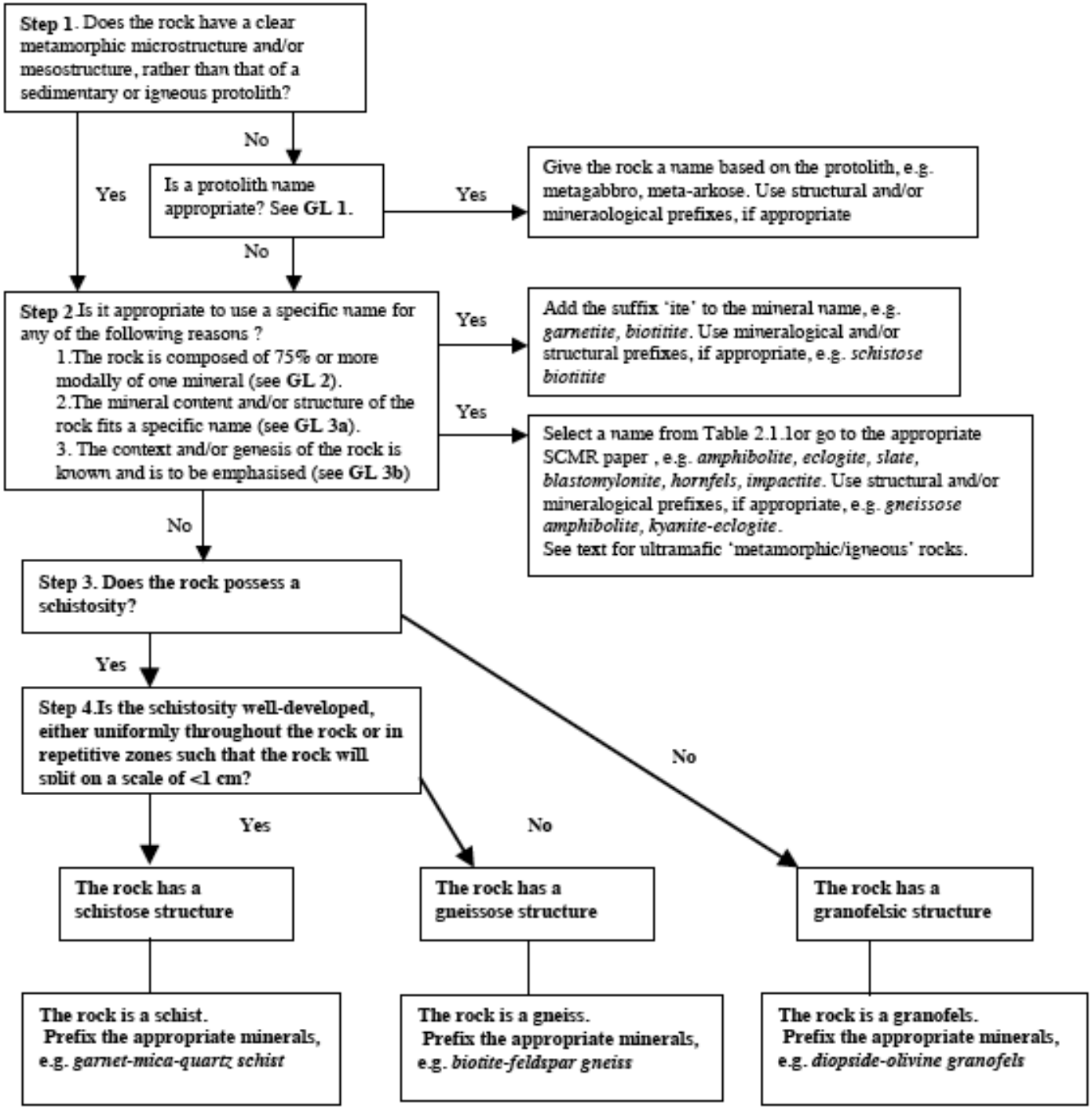


Texturas serpentiníticas: “mesh” com núcleos de olivina



Classificação de Rochas Metamórficas

- Rochas Metamórficas são classificadas com base em sua *textura* e *composição* (mineralógica ou química)
- A classificação é bastante simples e definida a partir de um fluxograma (IUGS 2007)
- Além do nome principal, pode-se escolher alguns prefixos para acentuar algum aspecto (e.g., origem do protólito, textura, mineralogia).


Step 1. Does the rock have a clear metamorphic microstructure and/or mesostructure, rather than that of a sedimentary or igneous protolith?
Yes
No
Is a protolith name appropriate? See GL 1.
Yes
Give the rock a name based on the protolith, e.g. metagabbro, meta-arkose. Use structural and/or mineraological prefixes, if appropriate
No
Step 2 Is it appropriate to use a specific name for any of the following reasons ?
1.The rock is composed of 75% or more modally of one mineral (see GL 2).
2.The mineral content and/or structure of the rock fits a specific name (see GL 3a).
3. The context and/or genesis of the rock is known and is to be emphasised (see GL 3b)
Yes
Add the suffix 'ite' to the mineral name, e.g. garnetite, biotitite. Use mineralogical and/or structural prefixes, if appropriate, e.g. schistose biotitite
Yes
Select a name from Table 2.1.1or go to the appropriate SCMR paper , e.g. amphibolite, eclogite, slate, blastomylonite, hornfels, impactite. Use structural and/or mineralogical prefixes, if appropriate, e.g. gneissose amphibolite, kyanite-eclogite.
See text for ultramafic 'metamorphic/igneous' rocks.
No
Step 3. Does the rock possess a schistosity?
Yes
Step 4.Is the schistosity well-developed, either uniformly throughout the rock or in repetitive zones such that the rock will split on a scale of <1 cm?
No
Yes
No
The rock has a schistose structure
The rock has a gneissose structure
The rock has a granofelsic structure
The rock is a schist.
Prefix the appropriate minerals, e.g. garnet-mica-quartz schist
The rock is a gneiss.
Prefix the appropriate minerals, e.g. biotite-feldspar gneiss
The rock is a granofels.
Prefix the appropriate minerals, e.g. diopside-olivine granofels

Rochas Metamórficas Foliadas

Ardósia / Slate: **compact, very fine-grained, metamorphic rock with a well-developed cleavage. Freshly cleaved surfaces are dull**

Filito / Phyllite: **a rock with a schistosity in which very fine phyllosilicates (sericite/ phengite and/or chlorite), although rarely coarse enough to see unaided, impart a silky sheen to the foliation surface. Phyllites with both a foliation and lineation are very common.**

Figure 22.1. Examples of foliated metamorphic rocks. a. Slate. b. Phyllite. Note the difference in reflectance on the foliation surfaces between a and b: phyllite is characterized by a satiny sheen. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Rochas Metamórficas Foliadas

Xisto / Schist: a metamorphic rock exhibiting a schistosity. By this definition schist is a broad term, and slates and phyllites are also types of schists. In common usage, schists are restricted to those metamorphic rocks in which the foliated minerals are coarse enough to see easily in hand specimen.

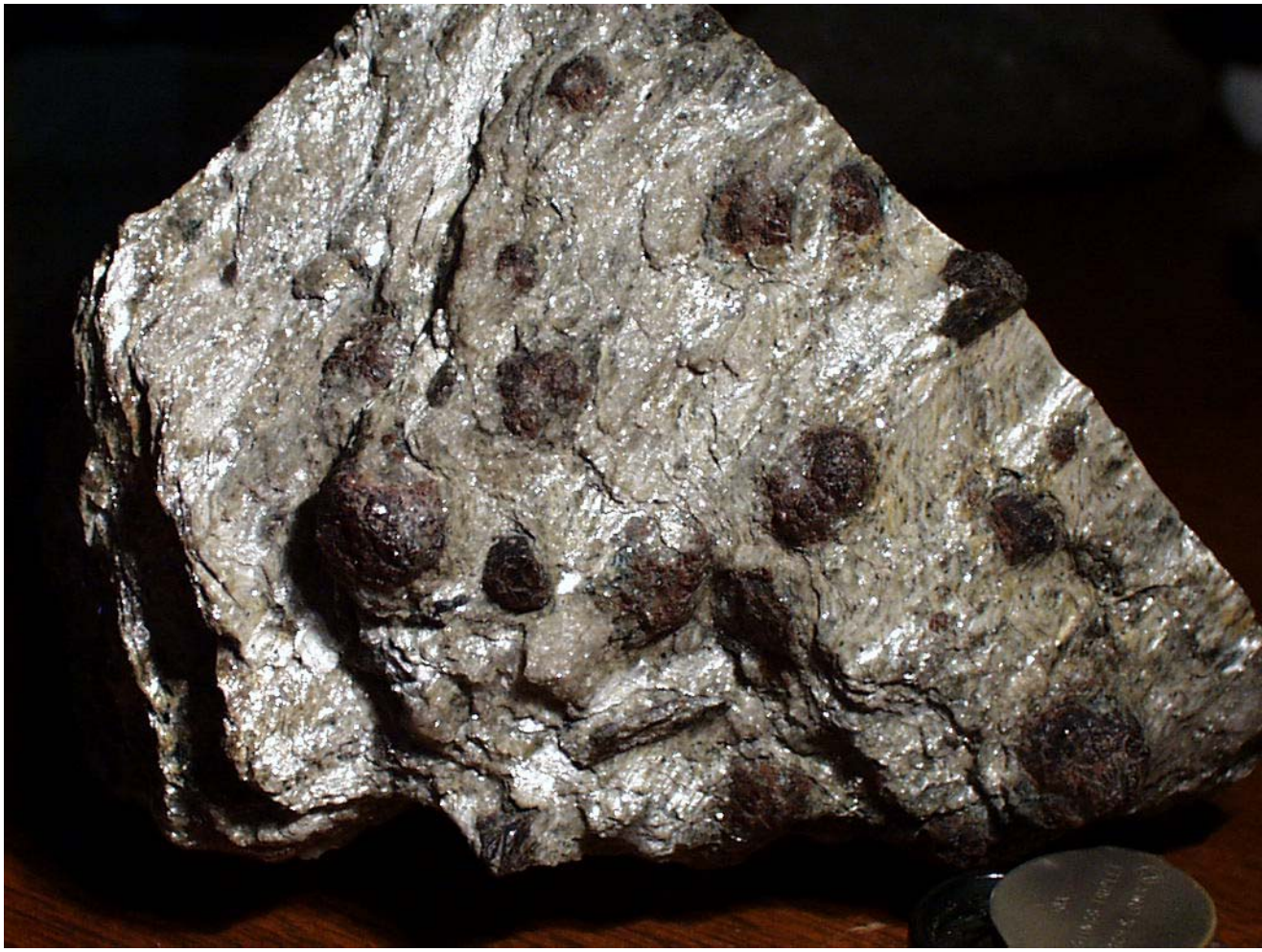


Figure 22.1c. Garnet muscovite schist. Muscovite crystals are visible and silvery, garnets occur as large dark porphyroblasts. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Rochas Metamórficas Foliadas

Gnaisse / Gneiss: a metamorphic rock displaying gneissose structure. Gneisses are typically layered (also called banded), generally with alternating felsic and darker mineral layers. Gneisses may also be lineated, but must also show segregations of felsic-mineral-rich and dark-mineral-rich concentrations.

Figure 22.1d. Quartzo-feldspathic gneiss with obvious layering. Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Rochas Metamórficas Não Foliadas

Mais simples que as rochas foliadas

Granofels: designa qualquer rocha isotrópica (sem orientação preferencial); é um termo essencialmente textural.

Hornfels: é um tipo de granofels muito fino e compacto, que ocorre ao redor de corpos intrusivos; é um termo genético e determina que aquela rocha foi formada pelo efeito de aquecimento e migração de fluidos da intrusão adjacente.

Nomes Metamórficos Específicos

Mármore: rocha metamórfica composta predominantemente por calcita e dolomita. O protólito é um calcário ou um dolomito.

Quartzite: rocha metamórfica composta predominantemente por quartzo. O protólito é em geral um arenito

Mármore:

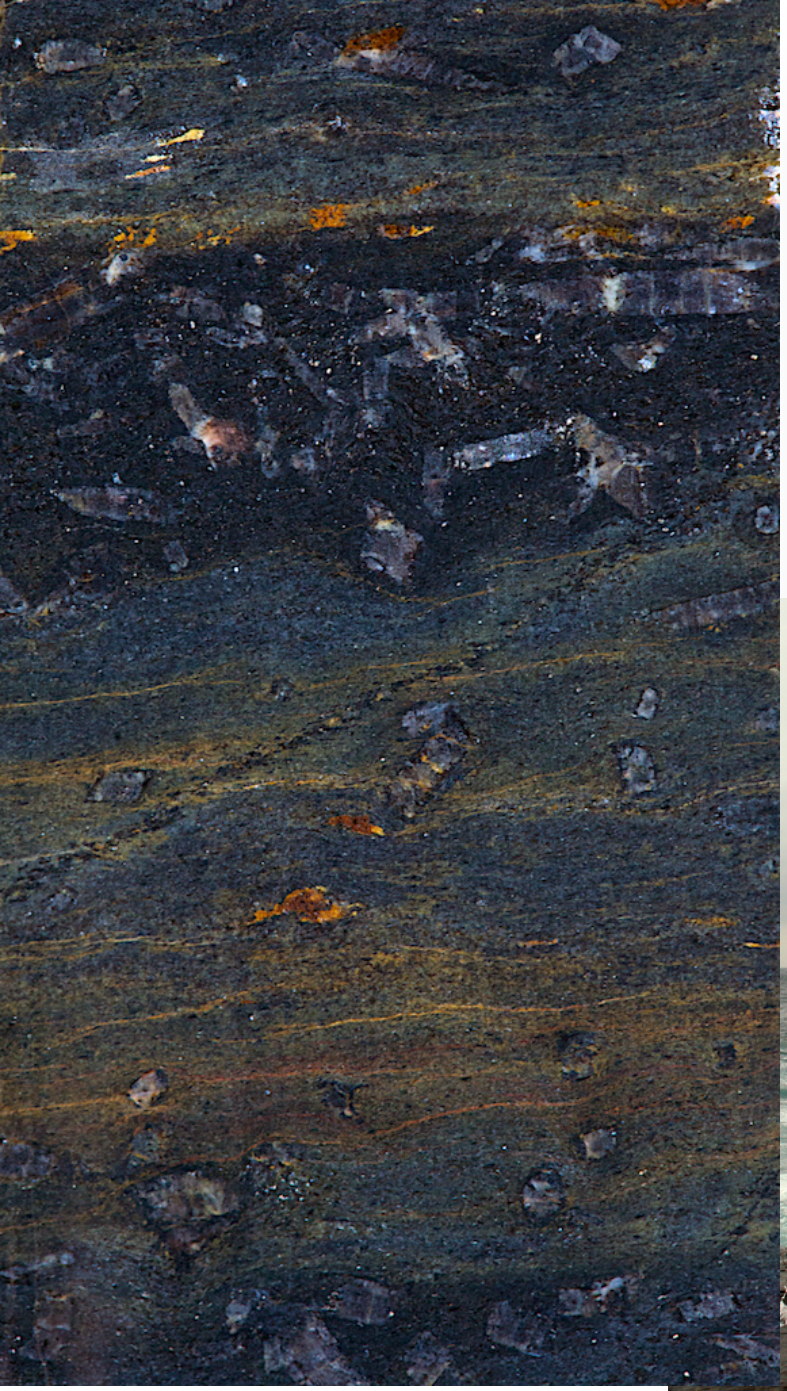
Carbonato quando sofre metamorfismo vira…


Pedredira Carrara, Itália


Panteon, Roma

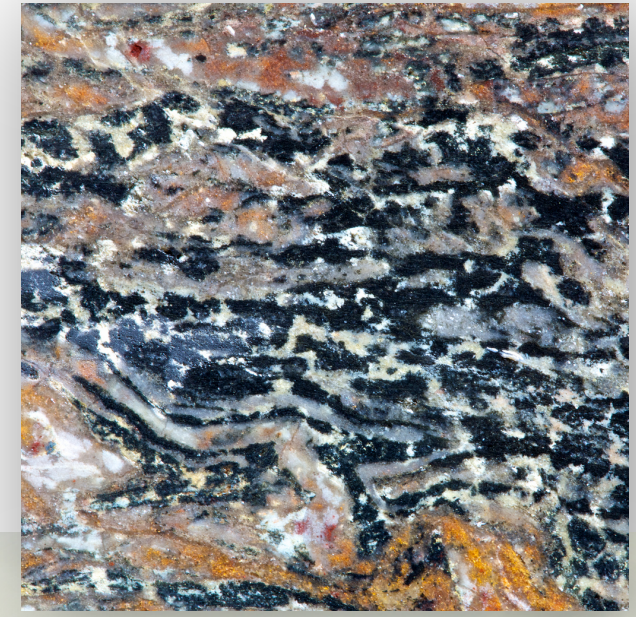
David, Bernini


Panteon, Roma



Hornfels, de cordierita, Skiddaw Granite, Escócia

Hornfels, de turmalina e quartzo, Cornuália, UK



Hornfels:

Metamorfismo junto a uma intrusão

Hornfels de Susa, Yamaguchi, Japão

Nomes Metamórficos Específicos

Serpentinito: deriva do metamorfismo em baixo grau de rochas ultramáficas; contém dominantemente serpentina;

Anfibolito: rocha metamórfica contendo principalmente hornblende + plagioclase. Anfibolitos podem ser foliados ou não e o protólito pode ser tanto ígneo, quanto uma grauvaca.

Eclogito: rocha verde e vermelha, contendo clinopiroxênio e granada (onfacita + piropo). Resulta geralmente da desidratação da crosta oceânica.

Nomes Metamórficos Específicos

Skarn: rocha gerada por metamorfismo de contato em rochas com sílica e carbonato; o skarn contém minerais ricos em cálcio e silicato como: grossularita, epidoto, tremolita e vesuvianita.

Granulito: rocha de alto grau metamórfico, composta por minerais sem OH. Ortopiroxênio e plagioclásio são comuns, micas são ausentes.

Migmatito: rocha híbrida, formada por partes escuras (melanossoma) e partes claras (leucossoma). Os leucossomas em geral representam a parte que sofreu fusão e segregação local em escala de 1-10 cm.

Termos adicionais, que podem ser usados para dar nome às Rochas Metamórficas:

Porfiroblástico: rochas que apresenta minerais metamórficos que cresceram muito mais do que a matriz.

Em algumas rochas de baixo grau, os porfiroblastos forma ‘pintas’ na rocha, como no caso do hornfels em torno do Granito de Skiddaw.

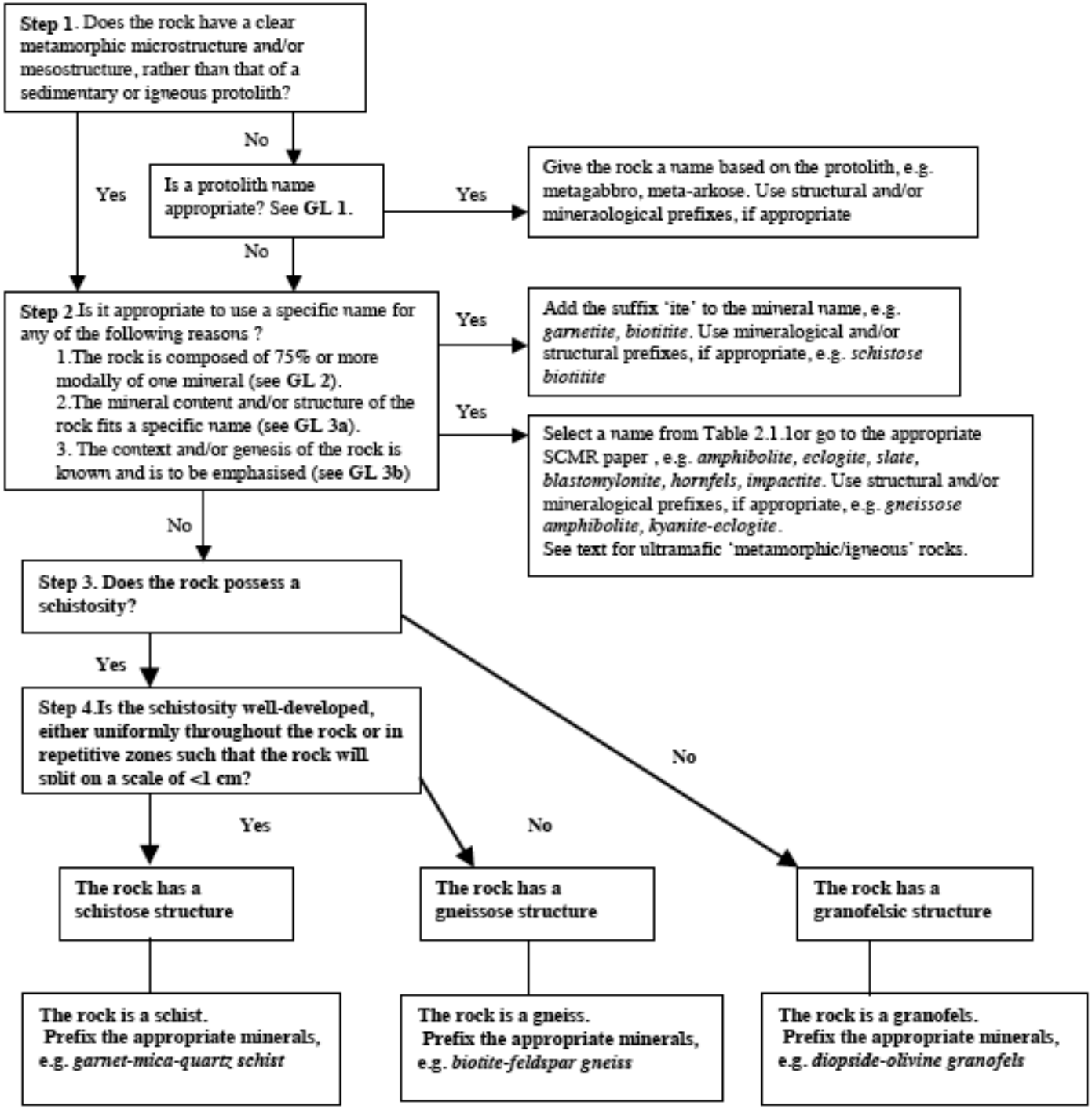
Augen gnaisse: Alguns gnaisses tem cristais com forma de ‘olhos’, em geral derivados de grandes cristais (comumente feldspatos) dos protólitos.

Orto- prefixo indicando um protólito ígneo;

Para- prefixo indicando um protólito sedimentar

Além desses termos pode-se acrescentar aspectos como tamanho de grão (fino, médio, grosso), cor, aspectos geoquímicos (aluminoso, calcáreo, máfico, félsico etc.)

Qual o nome desta rocha?


Step 1. Does the rock have a clear metamorphic microstructure and/or mesostructure, rather than that of a sedimentary or igneous protolith?
Yes
No
Is a protolith name appropriate? See GL 1.
Yes
Give the rock a name based on the protolith, e.g. metagabbro, meta-arkose. Use structural and/or mineraological prefixes, if appropriate
No
Step 2 Is it appropriate to use a specific name for any of the following reasons ?
1.The rock is composed of 75% or more modally of one mineral (see GL 2).
2.The mineral content and/or structure of the rock fits a specific name (see GL 3a).
3. The context and/or genesis of the rock is known and is to be emphasised (see GL 3b)
Yes
Add the suffix 'ite' to the mineral name, e.g. garnetite, biotitite. Use mineralogical and/or structural prefixes, if appropriate, e.g. schistose biotitite
Yes
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See text for ultramafic 'metamorphic/igneous' rocks.
No
Step 3. Does the rock possess a schistosity?
Yes
Step 4.Is the schistosity well-developed, either uniformly throughout the rock or in repetitive zones such that the rock will split on a scale of <1 cm?
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Yes
No
The rock has a schistose structure
The rock has a gneissose structure
The rock has a granofelsic structure
The rock is a schist.
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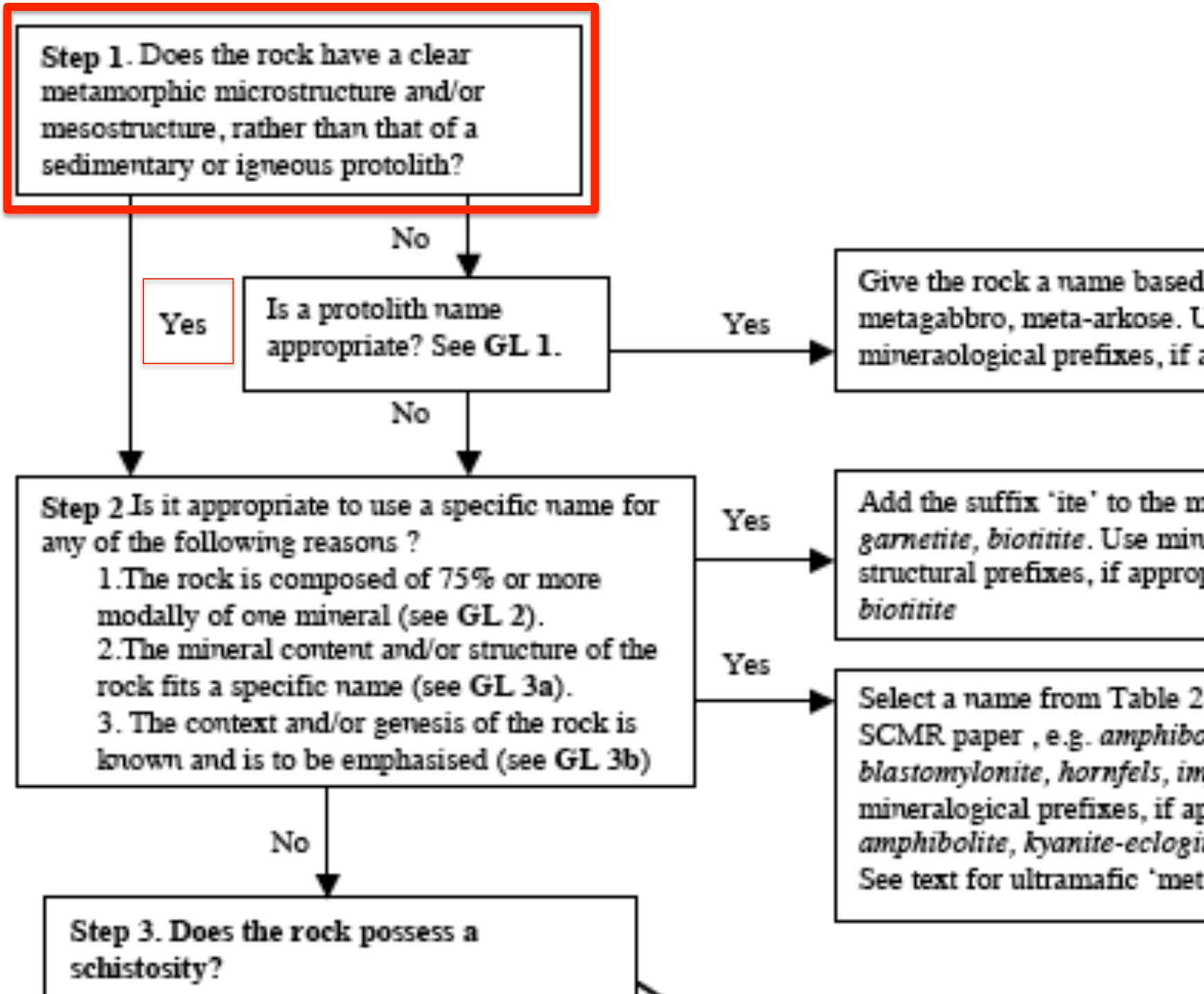
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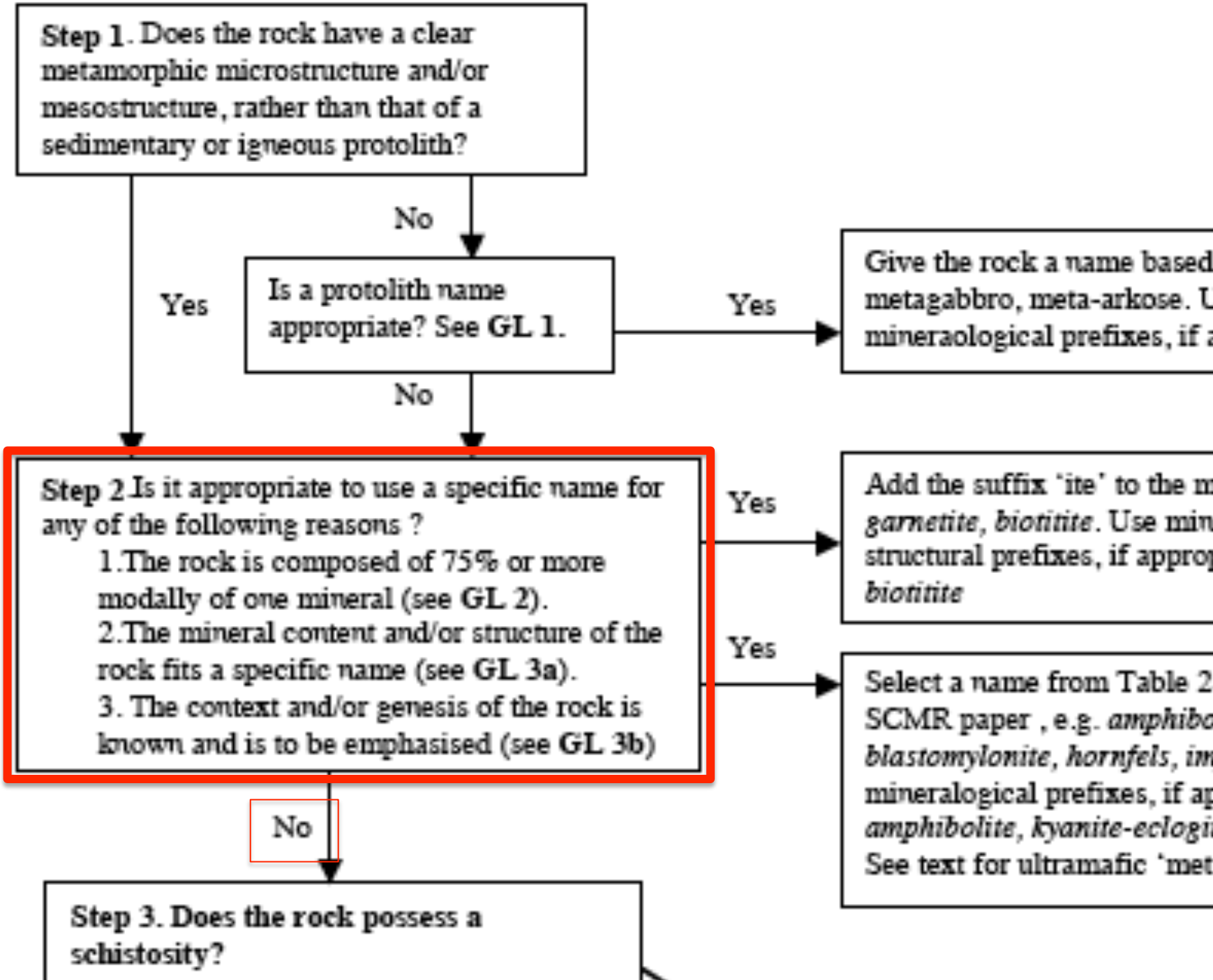
3. The context and/or genesis of the rock is known and is to be emphasised (see GL 3b)
Yes
Add the suffix 'ite' to the m
garnetite, biotitite. Use min
structural prefixes, if approp
biotitite
Yes
Select a name from Table 2
SCMR paper , e.g. amphibo
blastomylonite, hornfels, im
mineralogical prefixes, if ap
amphibolite, kyanite-eclogi
See text for ultramafic 'met
No
Step 3. Does the rock possess a schistosity?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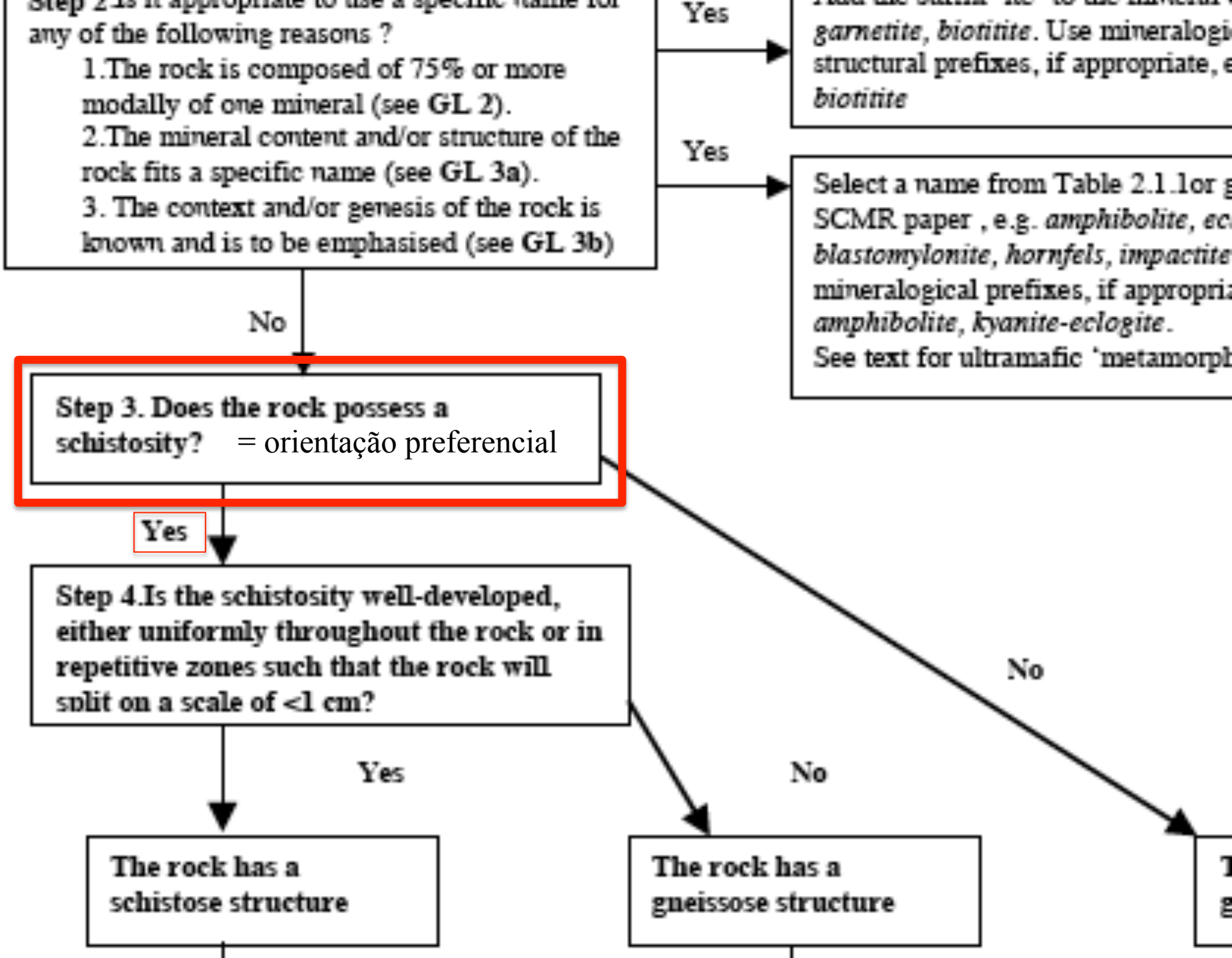
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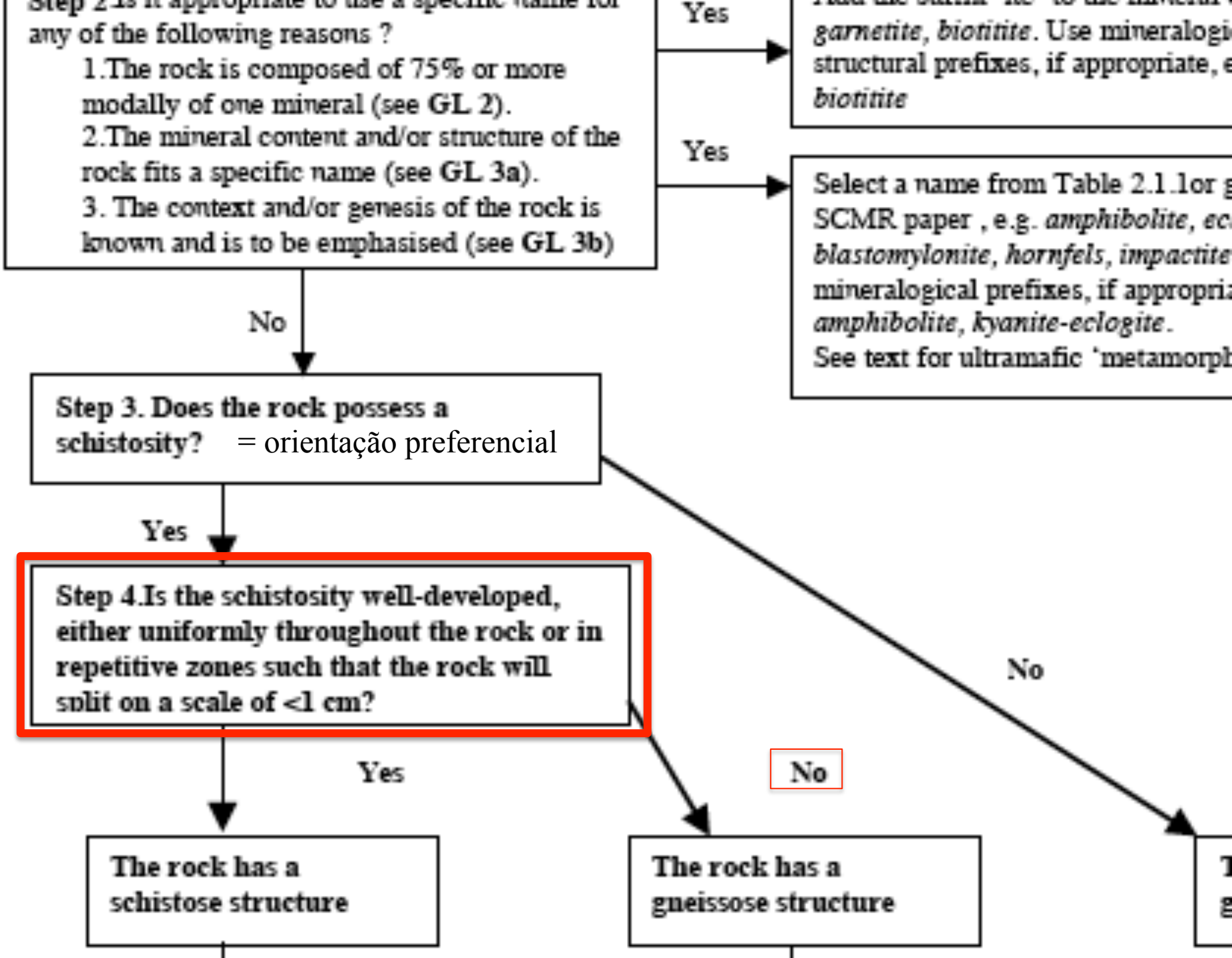
structural prefixes, if appropriate, e
biotitite
Yes
Select a name from Table 2.1.1or g
SCMR paper , e.g. amphibolite, ec
blastomylonite, hornfels, impactite
mineralogical prefixes, if appropri
amphibolite, kyanite-eclogite.
See text for ultramafic 'metamorph
No
Step 3. Does the rock possess a schistosity? = orientação preferencial
Yes
Step 4.Is the schistosity well-developed, either uniformly throughout the rock or in repetitive zones such that the rock will split on a scale of <1 cm?
No
Yes
No
The rock has a schistose structure
The rock has a gneissose structure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3. The context and/or genesis of the rock is known and is to be emphasised (see GL 3b)
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garnetite, biotitite. Use mineralogi
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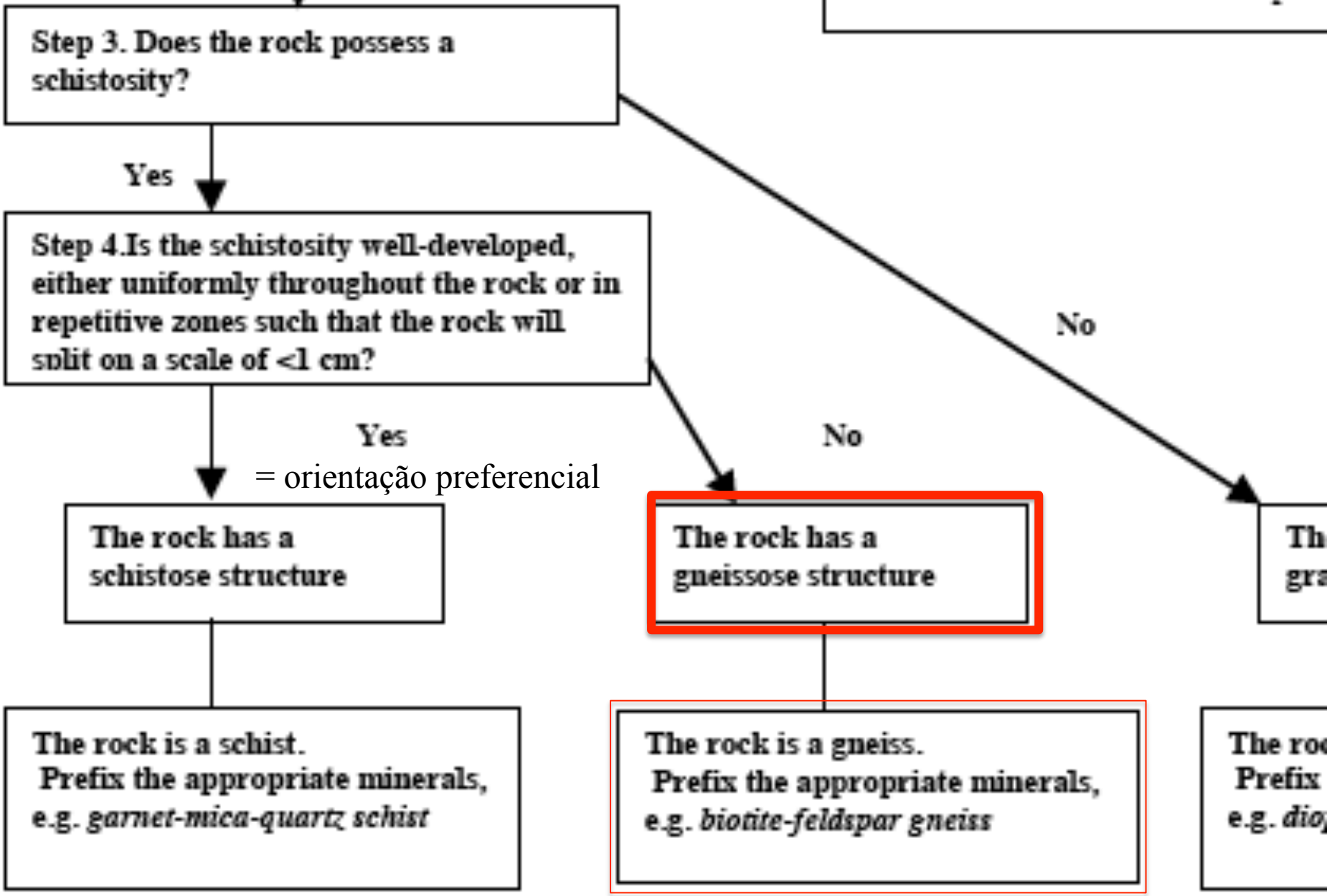
biotitite
Yes
Select a name from Table 2.1.1or g
SCMR paper , e.g. amphibolite, ec
blastomylonite, hornfels, impactite
mineralogical prefixes, if appropri
amphibolite, kyanite-eclogite.
See text for ultramafic 'metamorph
No
Step 3. Does the rock possess a schistosity? = orientação preferencial
Yes
Step 4.Is the schistosity well-developed, either uniformly throughout the rock or in repetitive zones such that the rock will split on a scale of <1 cm?
No
Yes
No
The rock has a schistose structure
The rock has a gneissose structure


Step 3. Does the rock possess a schistosity?
Yes
No
Step 4.Is the schistosity well-developed, either uniformly throughout the rock or in repetitive zones such that the rock will split on a scale of <1 cm?
Yes
No
= orientação preferencial
The rock has a schistose structure
The rock has a gneissose structure
The rock is a schist. Prefix the appropriate minerals, e.g. garnet-mica-quartz schist
The rock is a gneiss. Prefix the appropriate minerals, e.g. biotite-feldspar gneiss

Qual o nome desta rocha?

É um GNAISSE,
Como é rico em feldspato (cor avermelhada)
e biotita (cor preta):
É um BIOTITA-FELDSPATO GNAISSE
Como tem textura AUGEN
É um **BIOTITA-FELDSPATO AUGEN GNAISSE**