

Základy petrologie sedimentárních hornin

1.roč., LS

2) Siliciklastické horniny

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ÚGP

(Ústav geologie a paleontologie)

koncept eroze-transport-sedimentace

hlavní komponenty:

zrna (křemen, živce, úlomky hornin – magmatitů, metamorfitů, starších sedimentů)

mezizrnová hmota

- matrix (primární, jemnozrnná)
- tmel/cement (sekundární, vzniká během diagenese, hrubě krystalický)

porozita (pórové/mezizrnové prostory nejsou vyplněny ani matrix ani tmelem)

klasifikace podle zrnitosti

psefit, psamit, aleurit, pelit, aleuropelit; rudit, arenit, lutit

T a b u l k a 1

Obecné názvy užívané pro klastické sedimenty a jejich vysvětlení /podle J. Konty 1972/

klasická řečtina	česky	petrografický termín	význam	latina	česky	petrografický termín	význam
pséfos	oblázek, štěrk	psefit	akumulace úlomků o velikosti nad 2 mm	rudus	valoun	rudit	akumulace úlomků o velikosti nad 2 mm
psammos	písek	psamit	akumulace pískových zrn o velikosti 2-0,063 mm	arena	písek	arenit	akumulace pískových zrn o velikosti 2-0,063 mm
aleuron	mouka	aleurit	akumulace prachových zrn /velikosti mezi 0,063 a 0,004 mm /	lutum	bahno	lutit	akumulace zrn a částic o velikosti pod 0,063 mm
pélos	jíl, bahno, bláto	pelit	akumulace jílových částic o velikosti pod 0,004 mm				

částice		velikost					sediment
klgsty	zaoblené	mm	Φ	mm			
balvan	blok	250	-8	256	Š T Ě R K	S L E P E N E C B R E K C I E	balvanitý
valoun	kámen	50	-6	64			hrubozrnný
valoun	kámen	10	-3	8			střednozrnný
valounek	kamínek	2	-1	2			drobnozrnný
zrno		1	0	1	P Í S E K	P Í S K O V E C	velmi hrubozrnný
		0,50	+1	0,50			hrubozrnný
		0,25	+2	0,25			střednozrnný
		0,10	+3	0,125			jemnozrnný
		0,05	+4	0,062			velmi jemnozrnný
		0,01	+8	0,004			
					P R A C H	P R A - C H O V E C	
					J Í L	J Í L O - V E C	

$$\Phi = -\log_2 D$$

D[mm]: Φ:

1 0,25

0,5 1

0,25 2

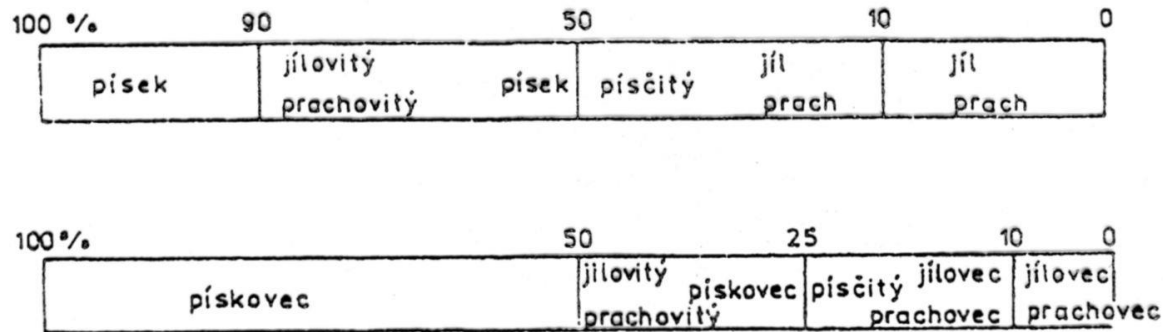
0,0625 4

Obr. 23

Klasifikace částic a z nich složených sedimentů podle velikosti (matrix nebo tmel neuvažujeme).

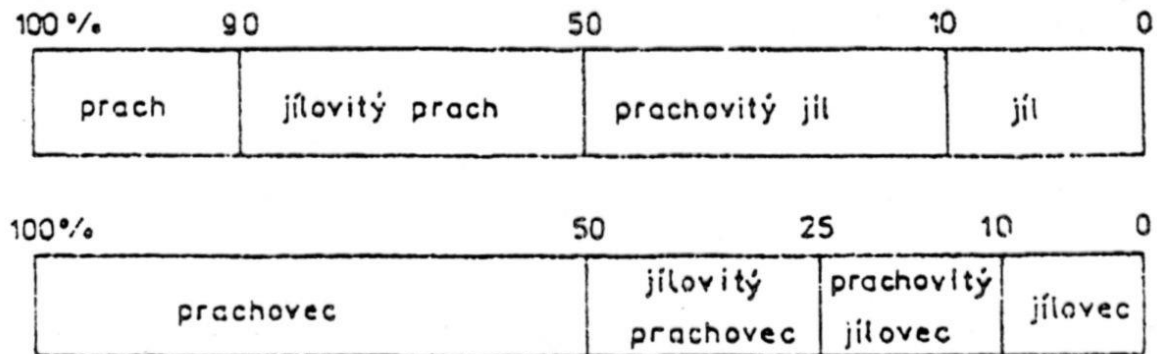
Table 2.3 Grain-size scale for sediments and sedimentary rocks.
After Udden and Wentworth, and Blair & McPherson (1999)

Length (mm)		Class	Sediment/ rock name	
	ϕ	block	mega- conglomerate	
4096	-12	boulder	gravel conglomerate	
2048	-11			vc
1024	-10			c
512	-9			m
256	-8			f
128	-7	cobble		
64	-6			c
32	-5	pebble		
16	-4			f
8	-3			m
4	-2		vc	
2	-1	granule		
1	0	sand	sand sandstone	
0.50	1			c
0.25	2			m
0.125	3			f
0.063	4			vf
0.031	5	silt	silt siltstone	
0.015	6			c
0.008	7			m
0.004	8			f
		clay	clay claystone	



Obr. 33

Klasifikace nezpevněných a zpevněných sedimentů tvořených směsí pískových zrn a jílu.

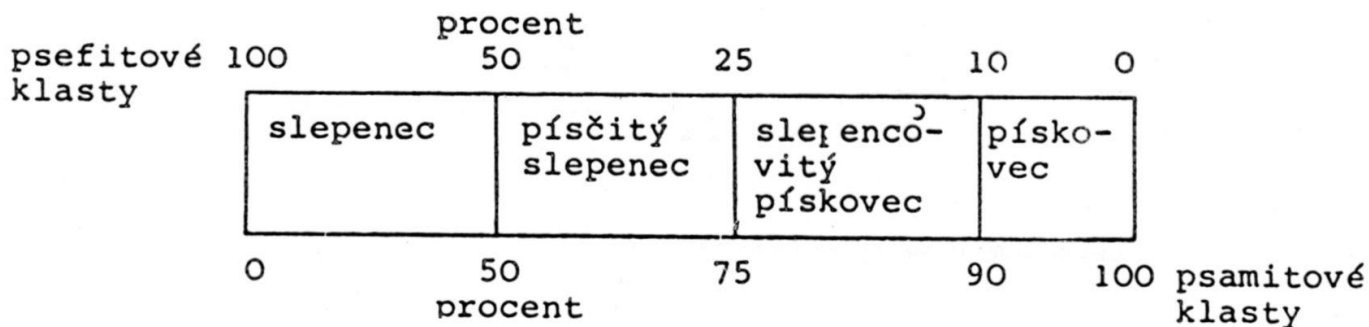


Obr. 40

Klasifikace nezpevněných a zpevněných sedimentů tvořených prachem a jílem.

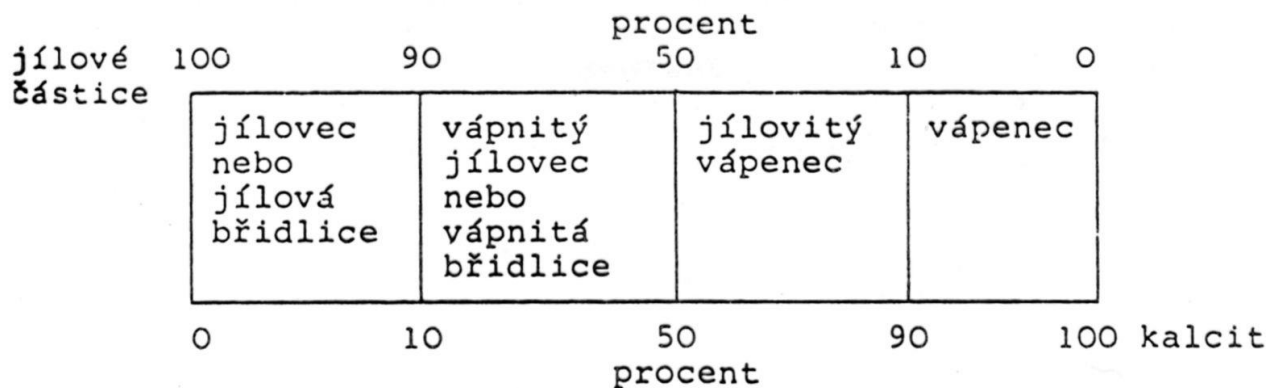
T a b u l k a 4

Pojmenování a procentuální rozhraní přechodných členů horninové řady slepenec-pískovec



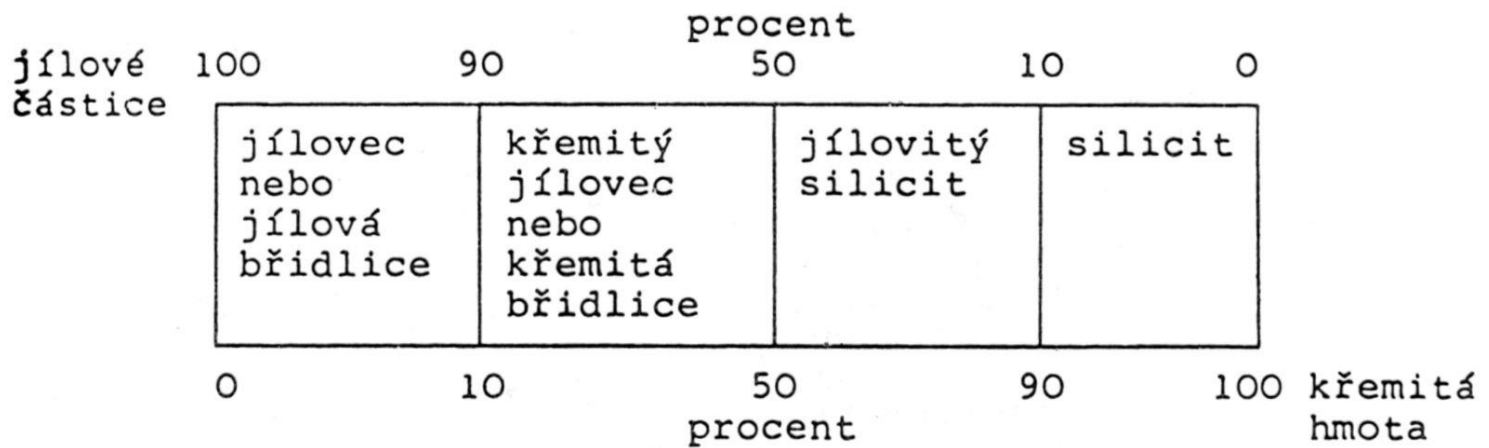
T a b u l k a 8

Pojmenování a procentuální rozhraní přechodných členů horninové řady jílovec /jílovitá břidlice/-vápenec

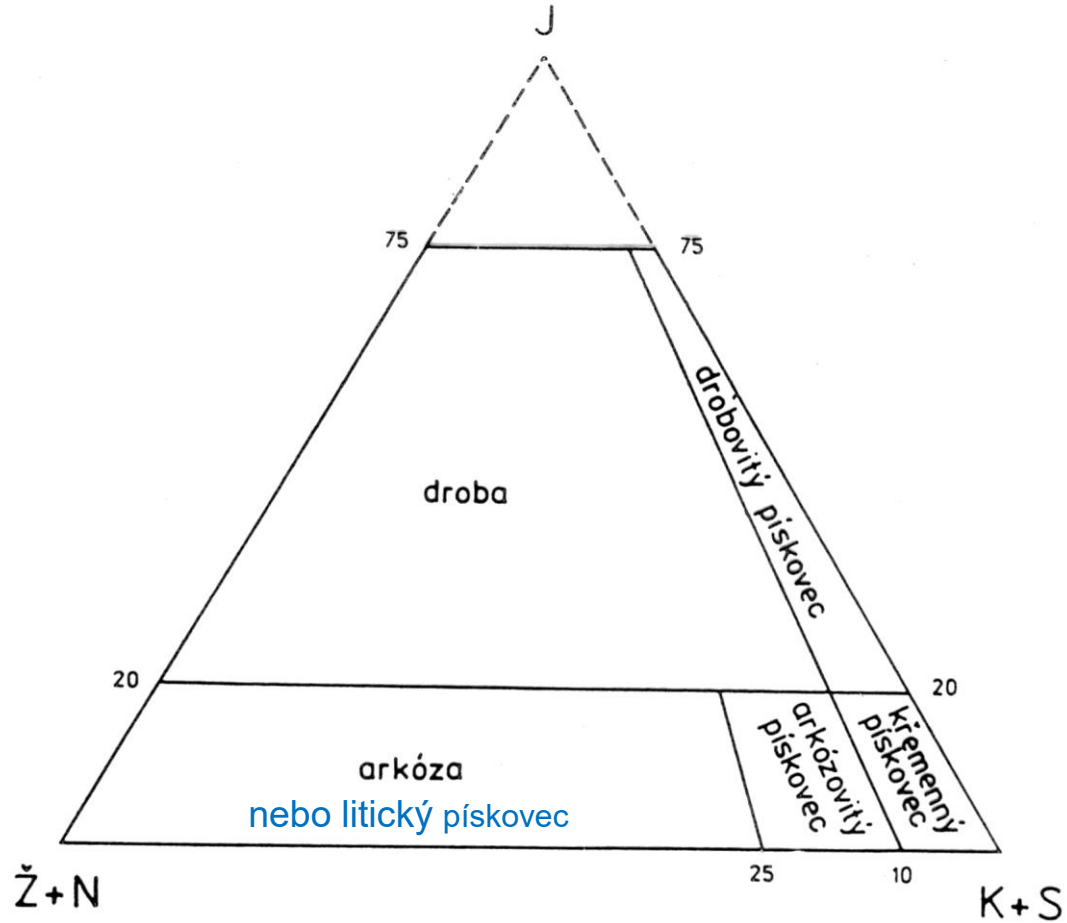


T a b u l k a 9

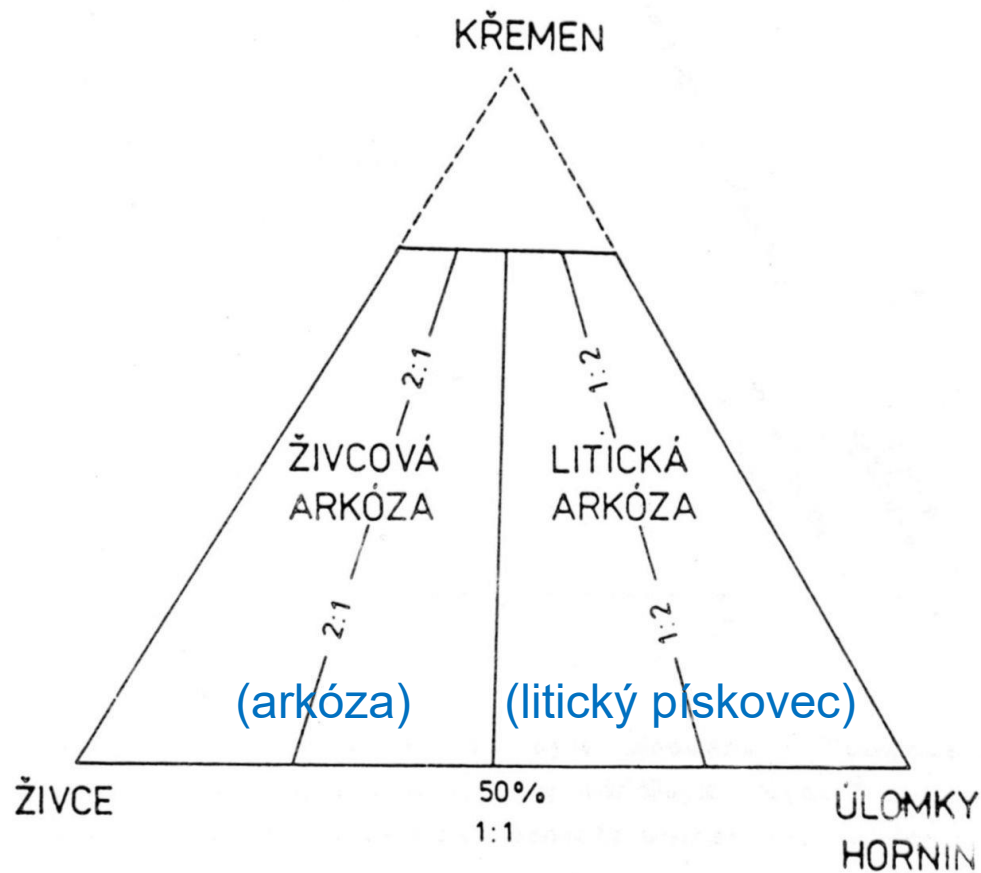
Pojmenování a procentuální rozhraní přechodných členů
horninové řady jílovec /jílovitá břidlice/-silicit



klasifikace podle složení



8. Používaná klasifikace pískovců, tak jak byla zavedena J. Petránkem et al. /1961/, Proti původnímu pojetí směřují čáry oddělující různé druhy pískovců do vrcholu trojúhelníka. Je to správnější, protože poměr mezi součástmi zůstává stejný



9. Základní dělení pískovců je na křemenné pískovce, drobovité pískovce, droby, arkózoité pískovce a arkózy /viz obr. 8/. Droby a arkózy, příp. i drobovité a arkózo-
vité pískovce můžeme dále dělit na živcové a litické. Dě-
lení je snadné, záleží na tom, převládají-li živce nad
úlomky hornin nebo naopak. Ne záleží na absolutních
procentech, ale na vzájemném poměru. Na trojúhelníku
je to znázorněno na příkladu arkóz, stejně postupujeme
i u drob

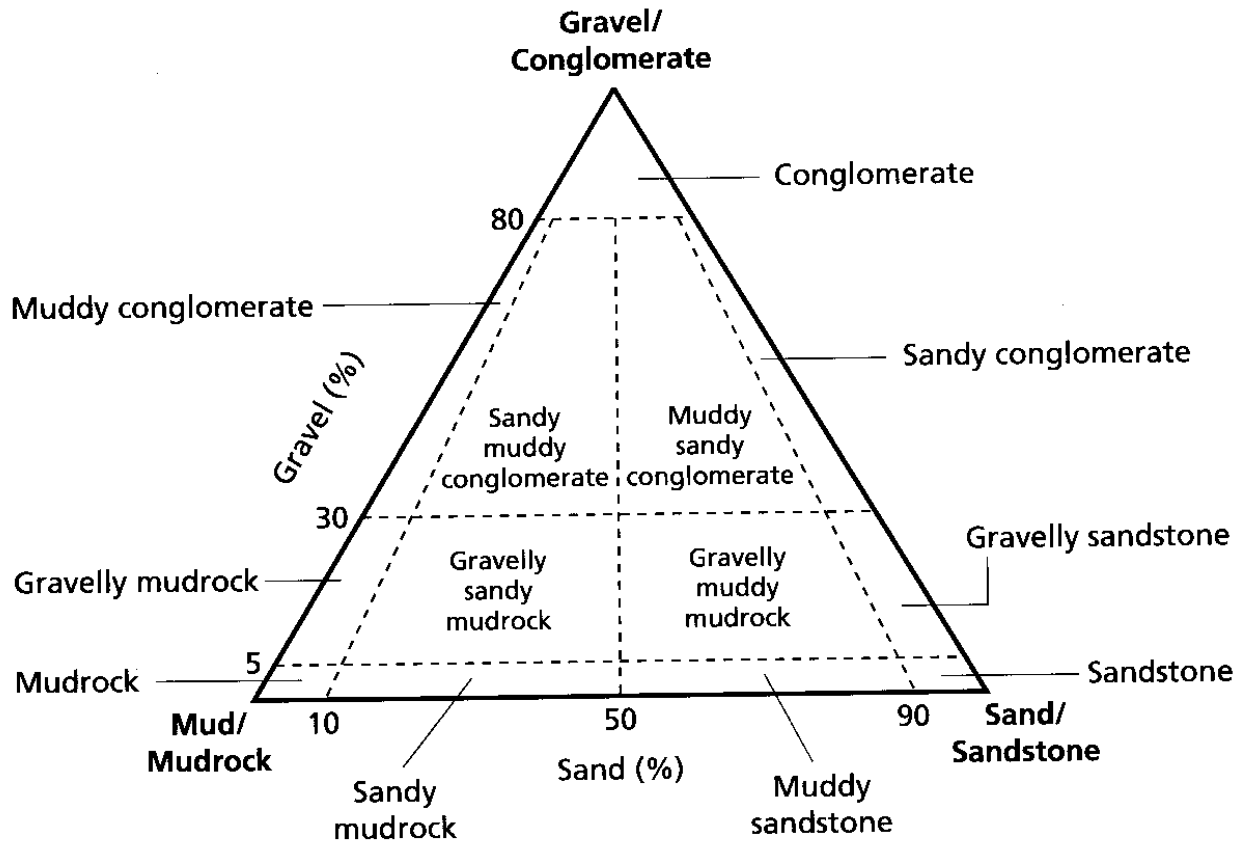
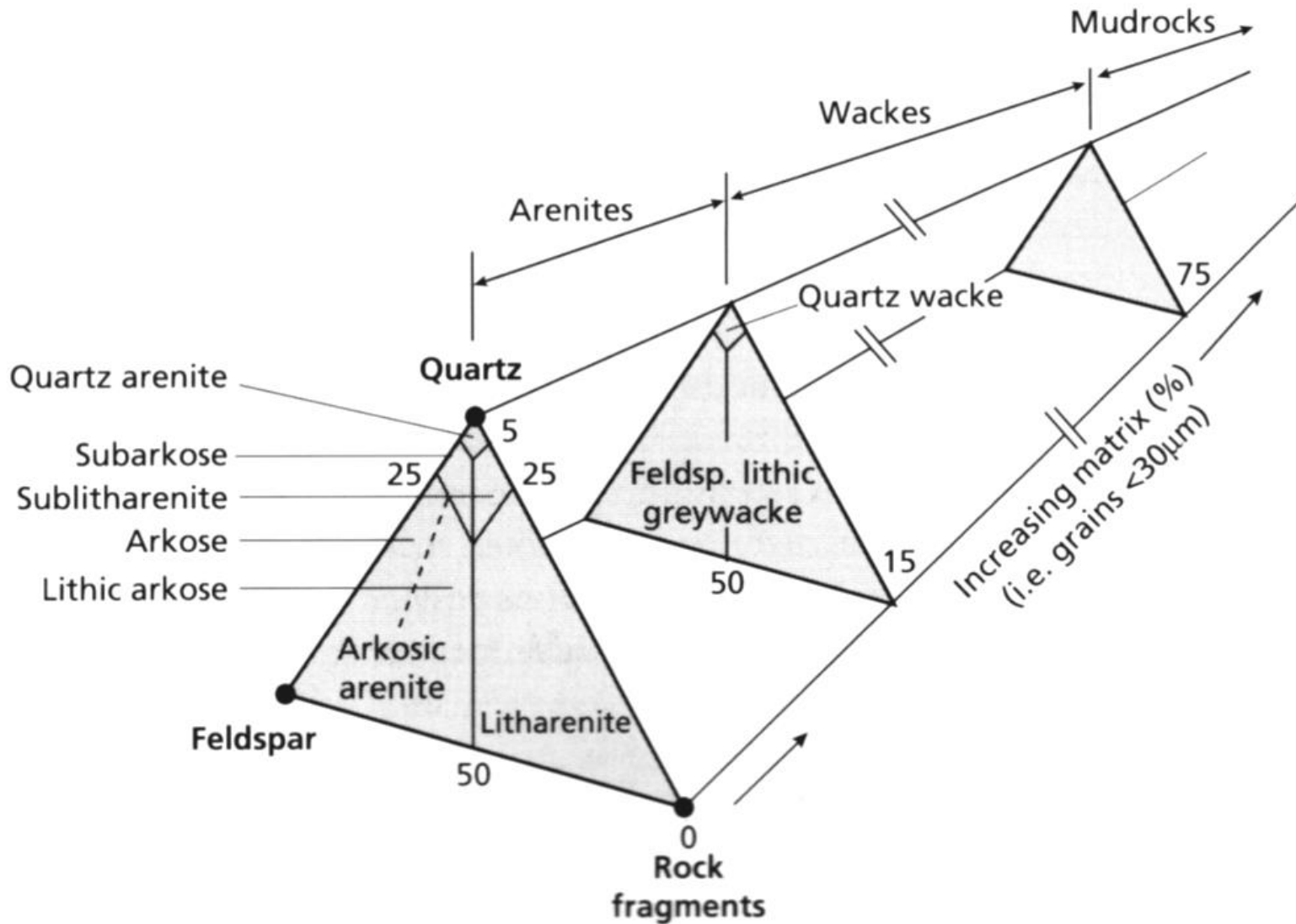


Fig. 2.1 Scheme for classifying sand–gravel–mud mixtures and the terms for sediment and rock (after Udden–Wentworth and Blair & McPherson, 1999).

droba



starší CZ literatura: EN:

MIKROSTRUKTURA

– STRUKTURA –

TEXTURE

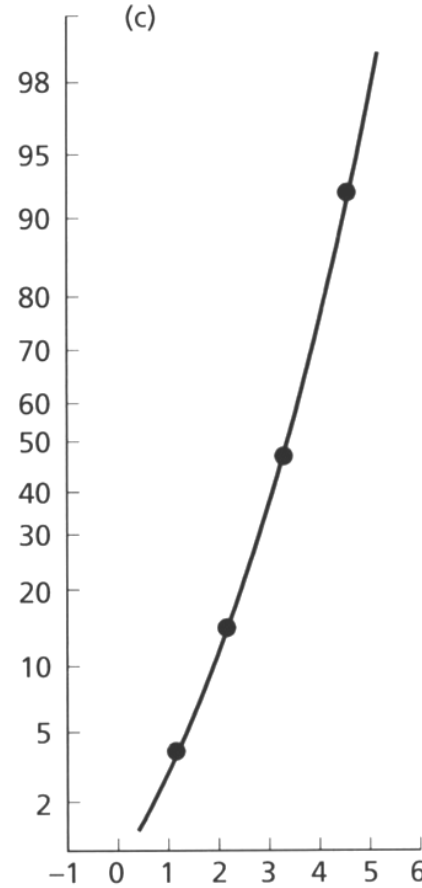
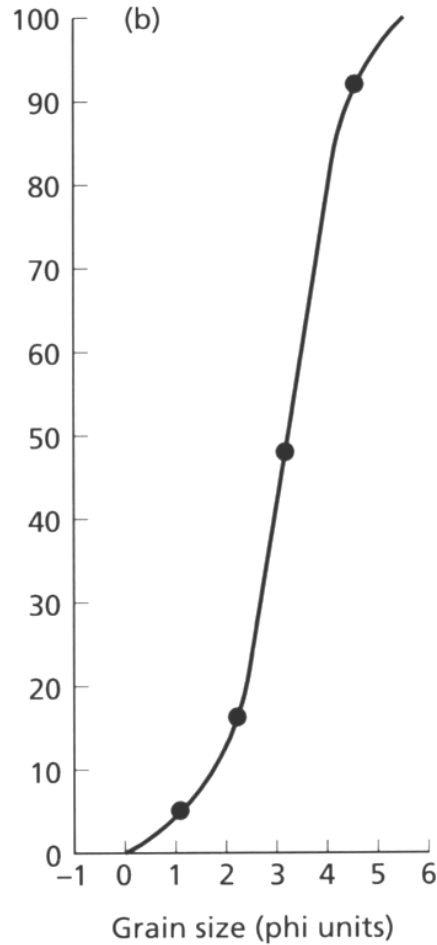
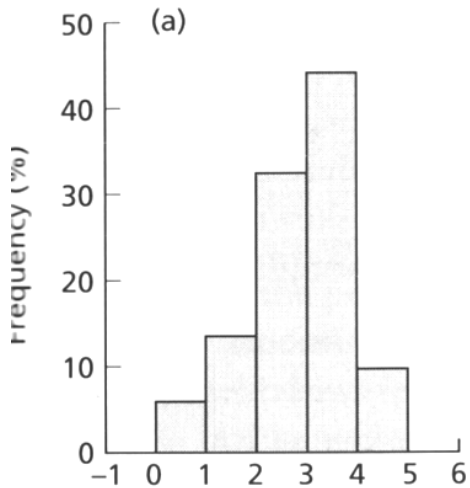
SEDIMENTÁRNÍ STRUKTURA – TEXTURA –

(SEDIMENTARY) STRUCTURE

mikrostruktury

zrnitost a granulometrie, vytrřídění, šikmost - kvantitativní metody

Class	Freq.	Freq. %	Cum. freq.
4-5	40	8	100
3-4	220	44	92
2-3	160	32	48
1-2	60	12	16
0-1	20	4	4

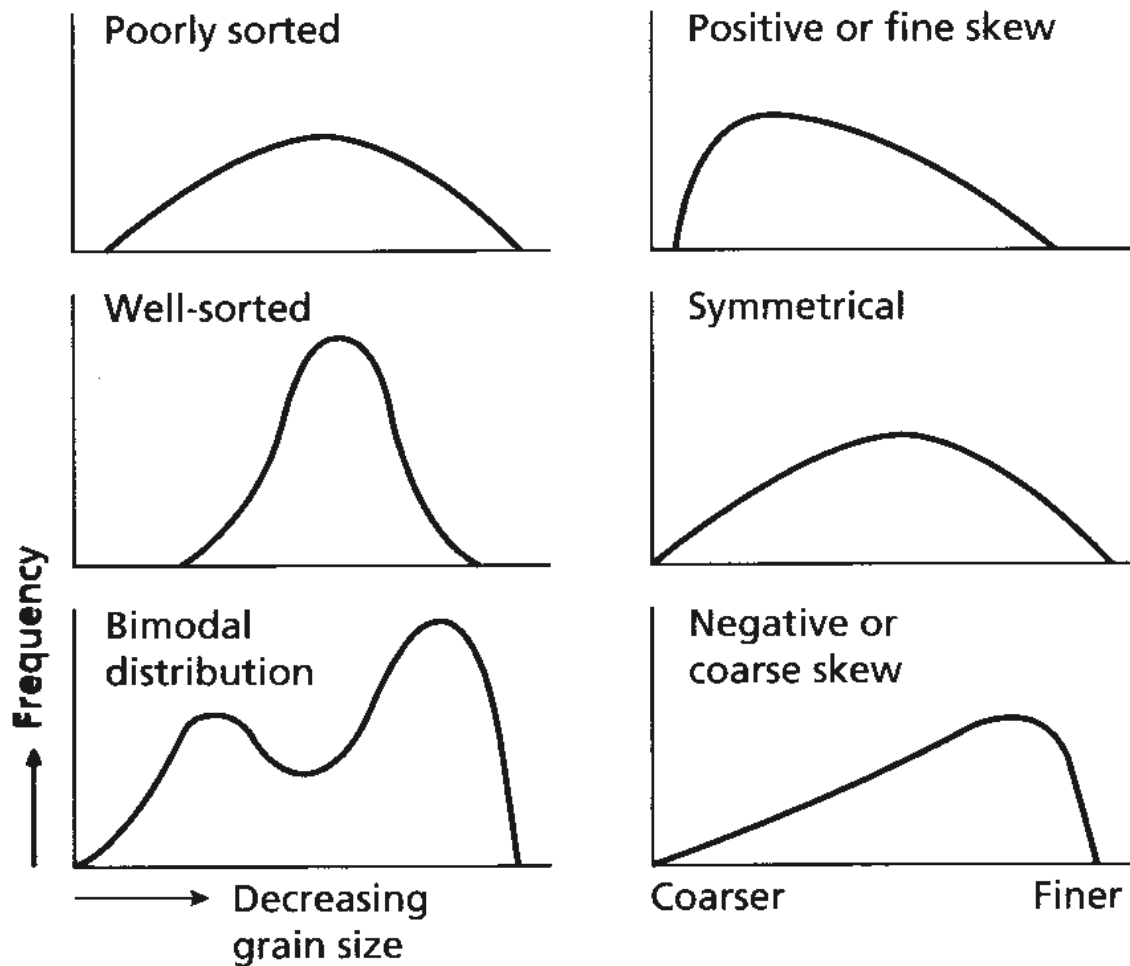


Grain size parameters derived graphically, Folk and Ward formulae

- median 3.05ϕ
- mean 2.95ϕ
- sorting 0.92 (moderately sorted)
- skewness -0.21 (coarse skew)
- kurtosis 0.96

$$\Phi = -\log_2 D$$

<u>D[mm]:</u>	<u>Φ:</u>
1	0,25
0,5	1
0,25	2
0,0625	4

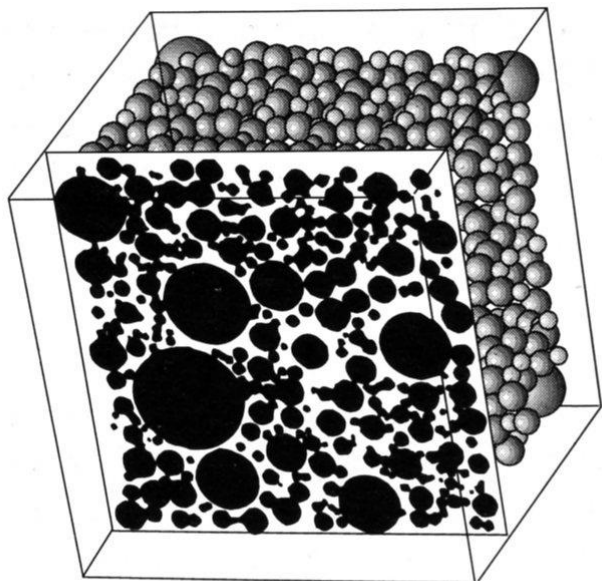


pozitivní šikmost

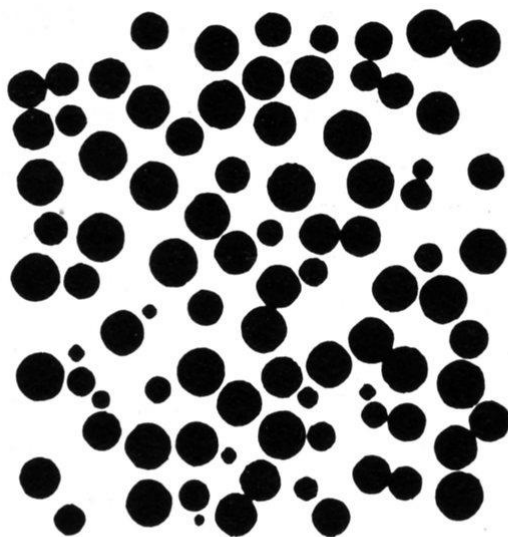
negativní šikmost

Fig. 2.2 Smoothed frequency distribution curves showing types of sorting and skewness.

vyřídění

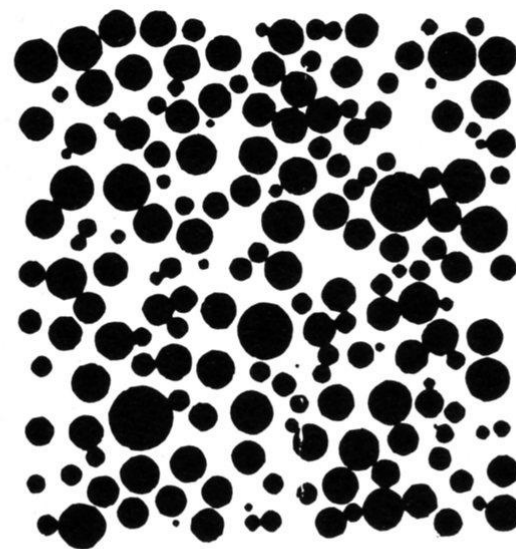


3-D dataset



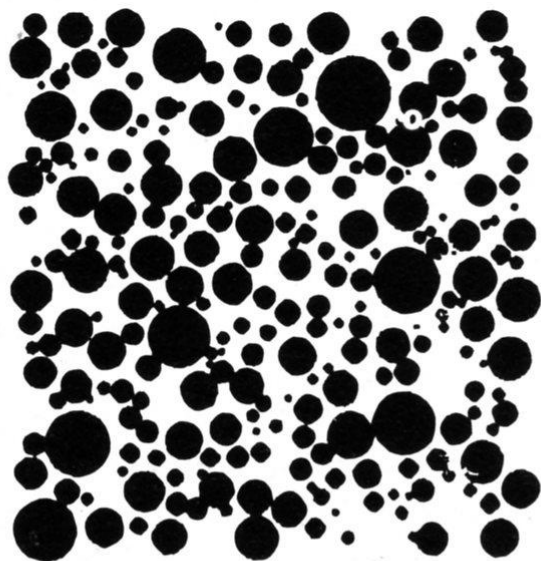
Very well sorted

$$\phi = 0.0$$



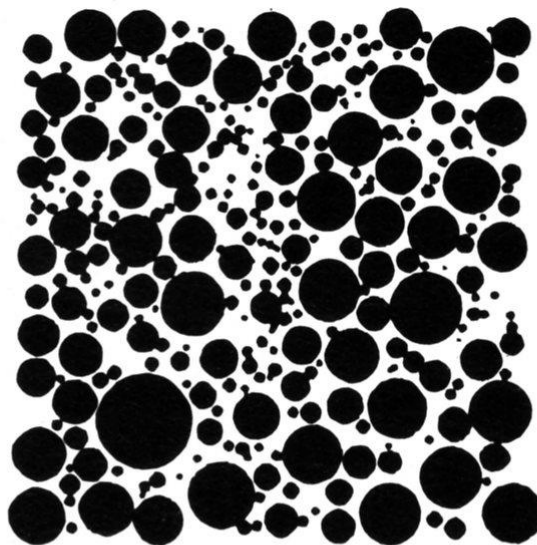
Well sorted

$$\phi = 0.36$$



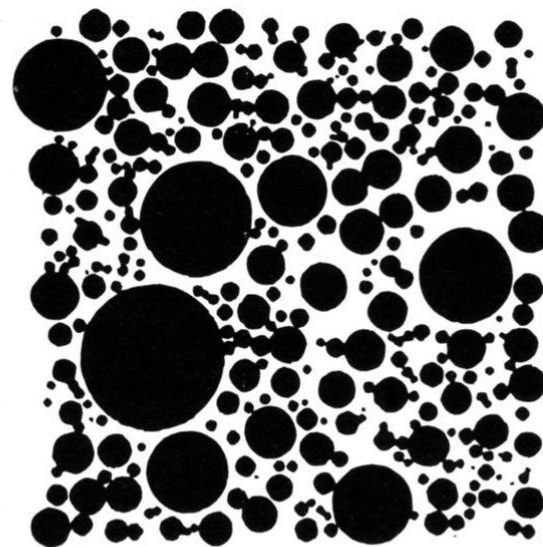
Moderately well sorted

$$\phi = 0.67$$



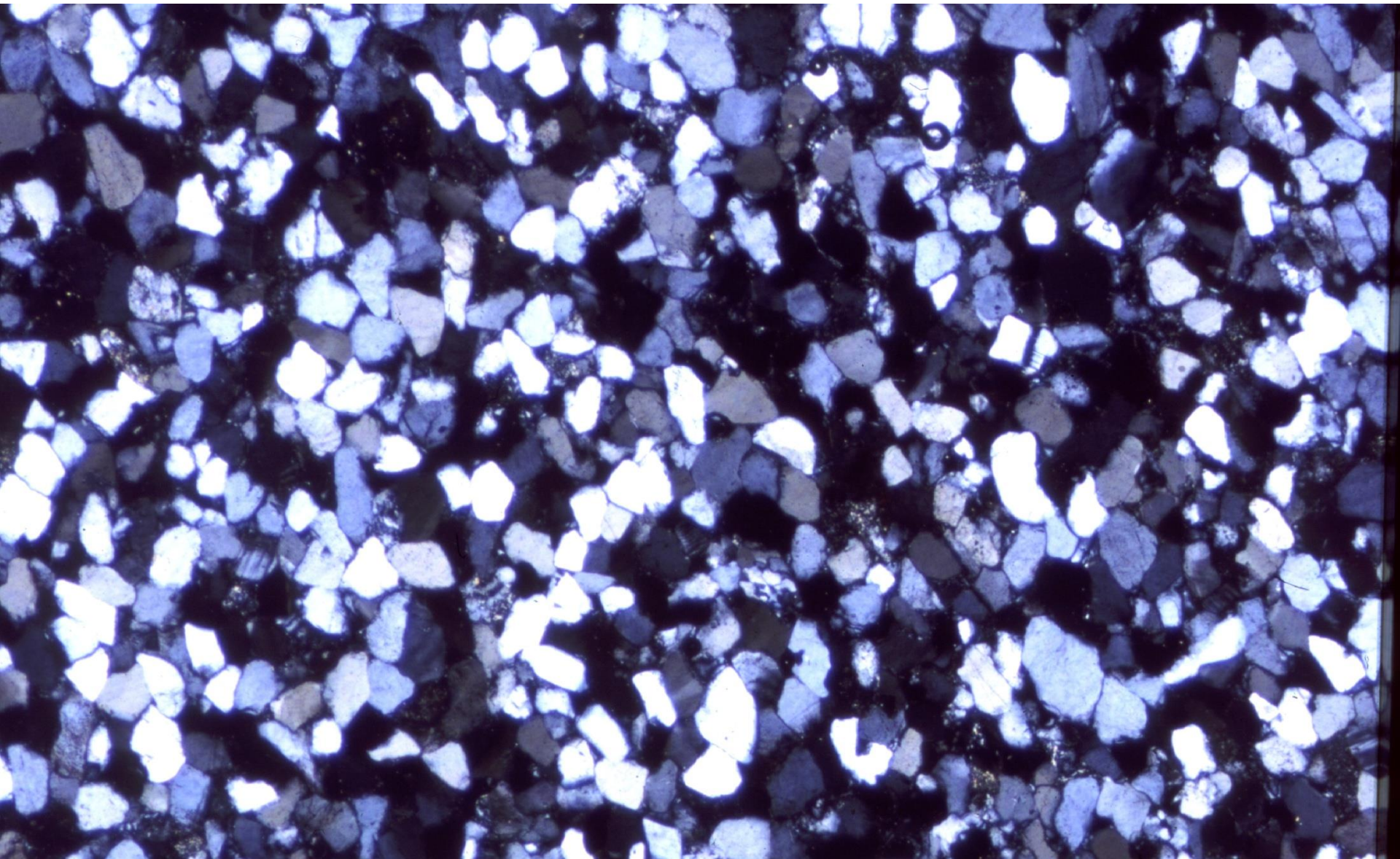
Moderately sorted

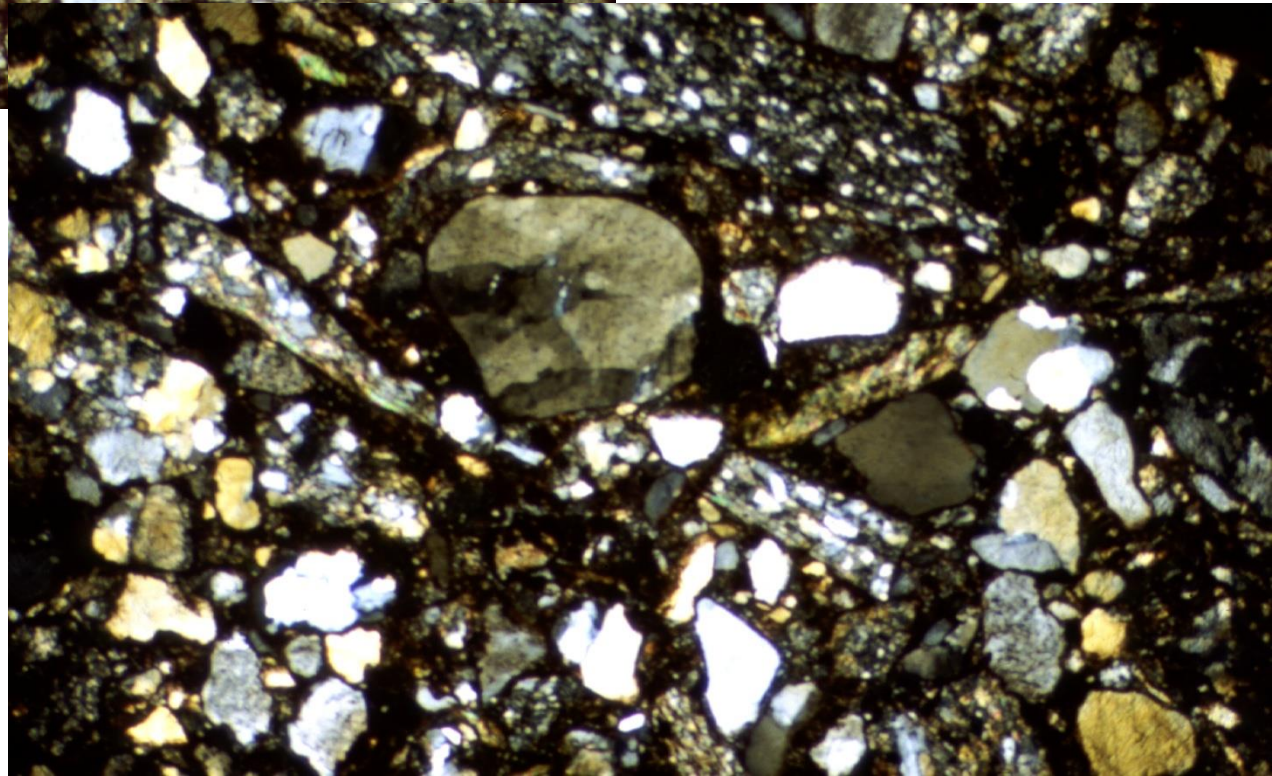
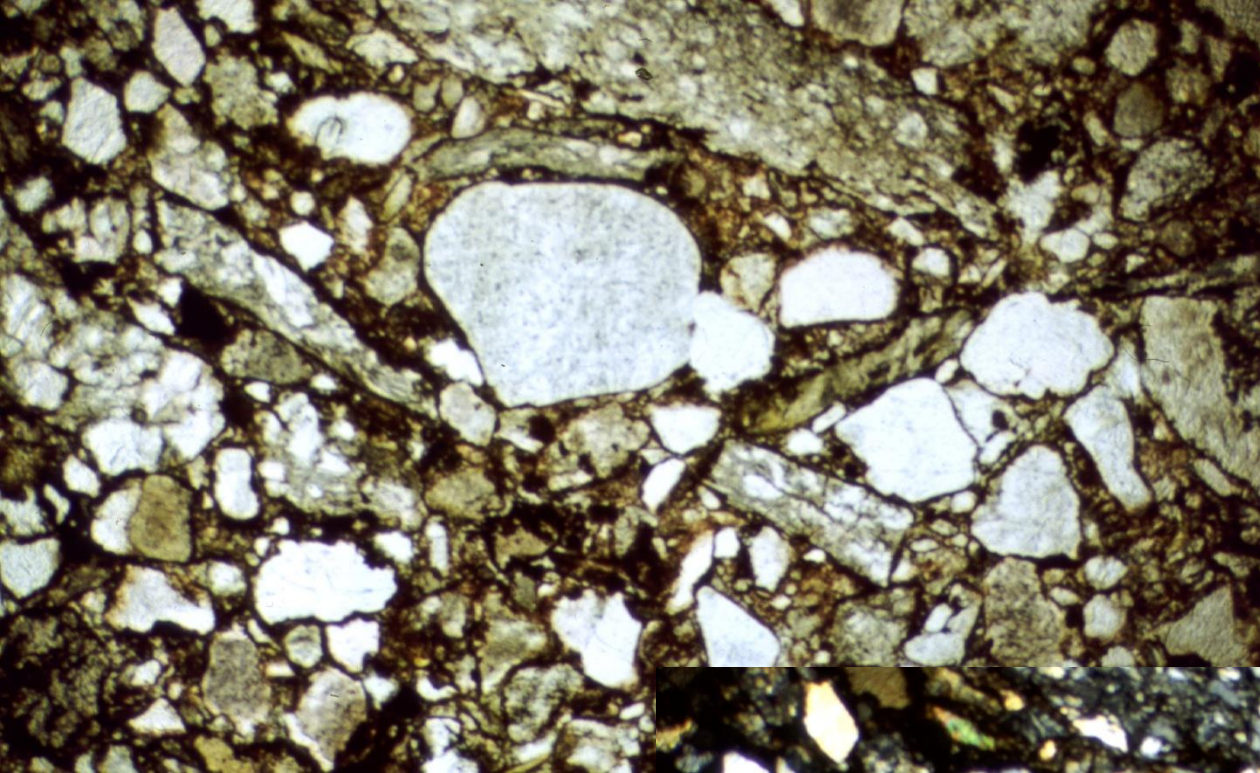
$$\phi = 0.74$$

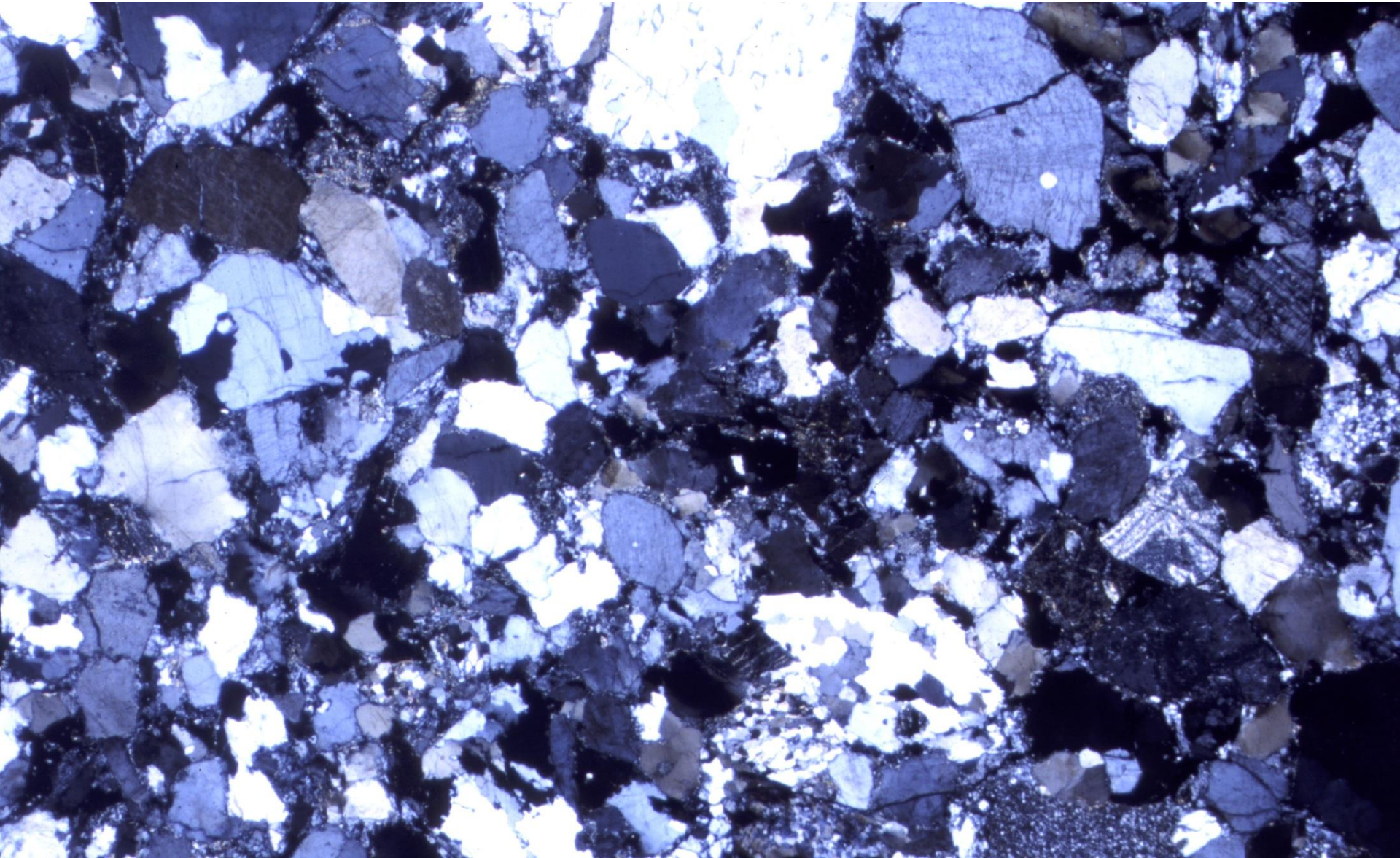


Poorly sorted

$$\phi = 1.15$$







sféricita

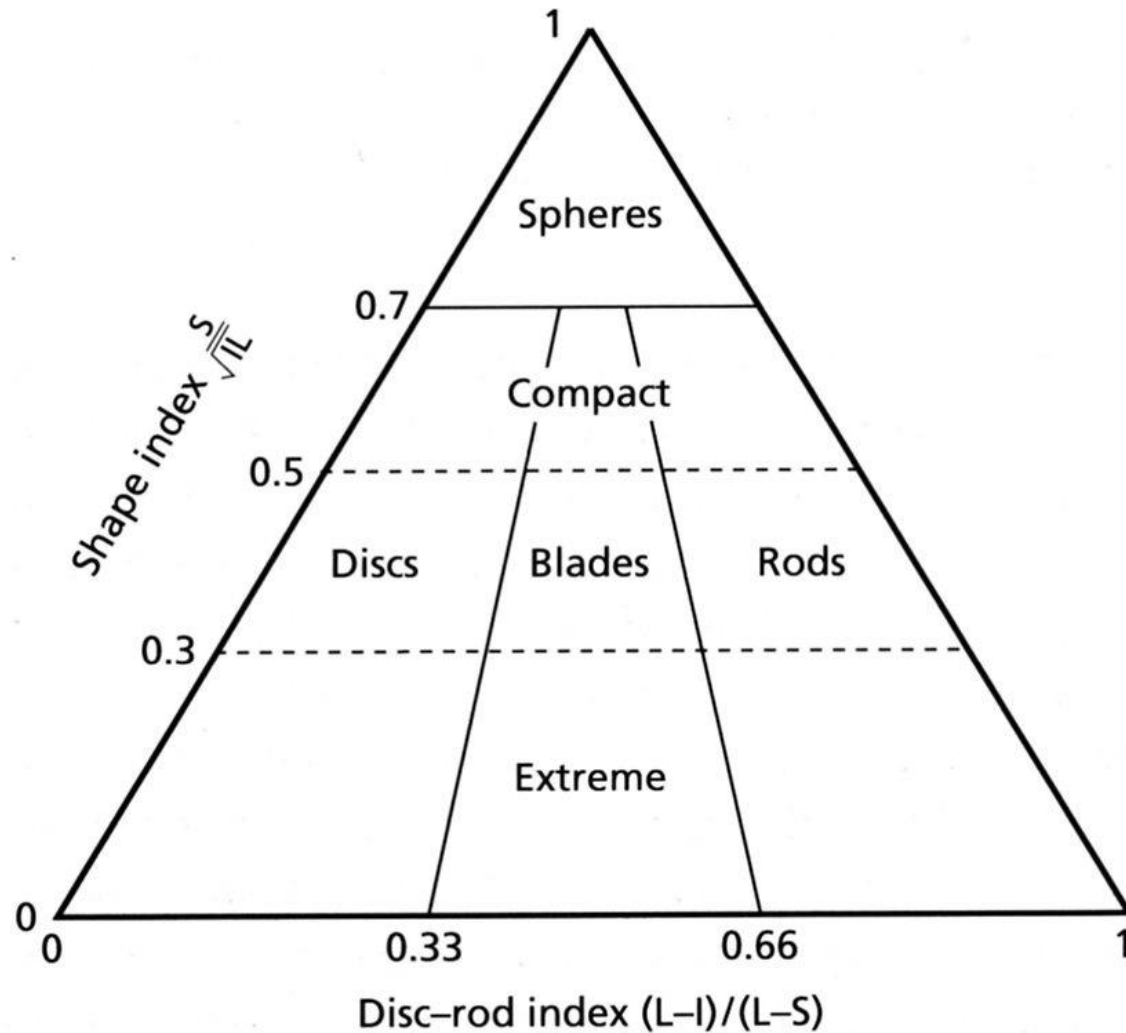


Fig. 2.5 The four classes of grain shape: spheres, discs, rods and blades, based on the shape index (a measure of the sphericity) and the disc-rod index. L, I and S represent the long, intermediate short axes of the grains, respectively (after Illenberger, 1991).

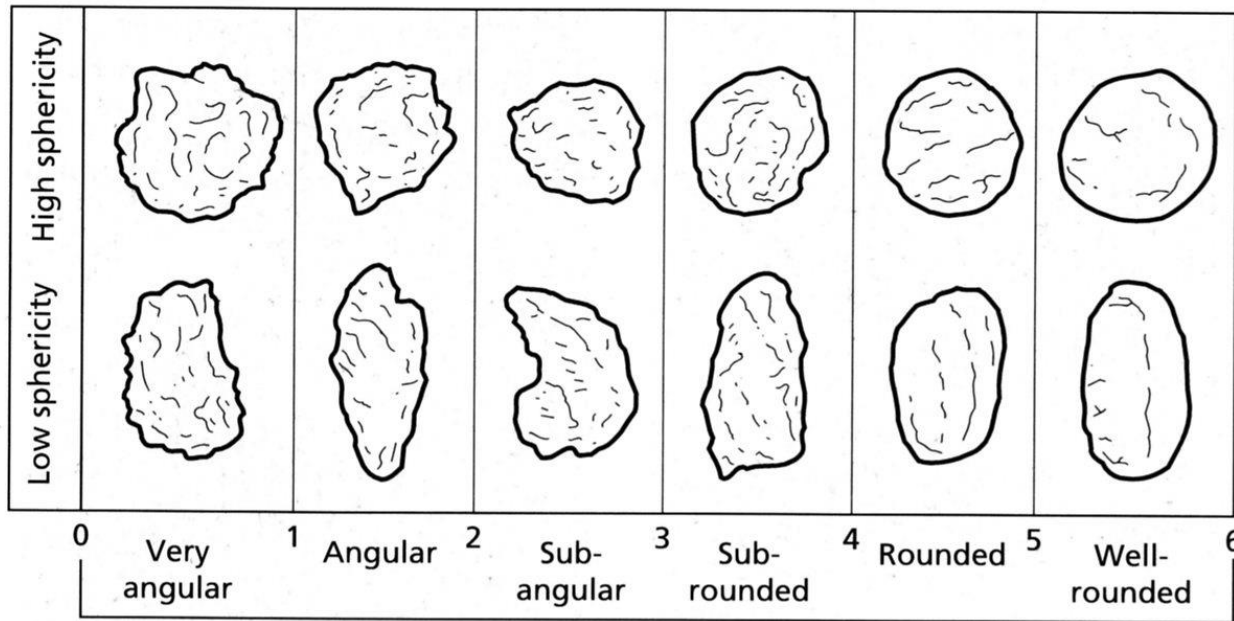


Fig. 2.6 Categories of roundness for sediment grains. For each category a grain of low and high sphericity is shown. After Pettijohn *et al.* (1987).

tvary a povrchy zrn

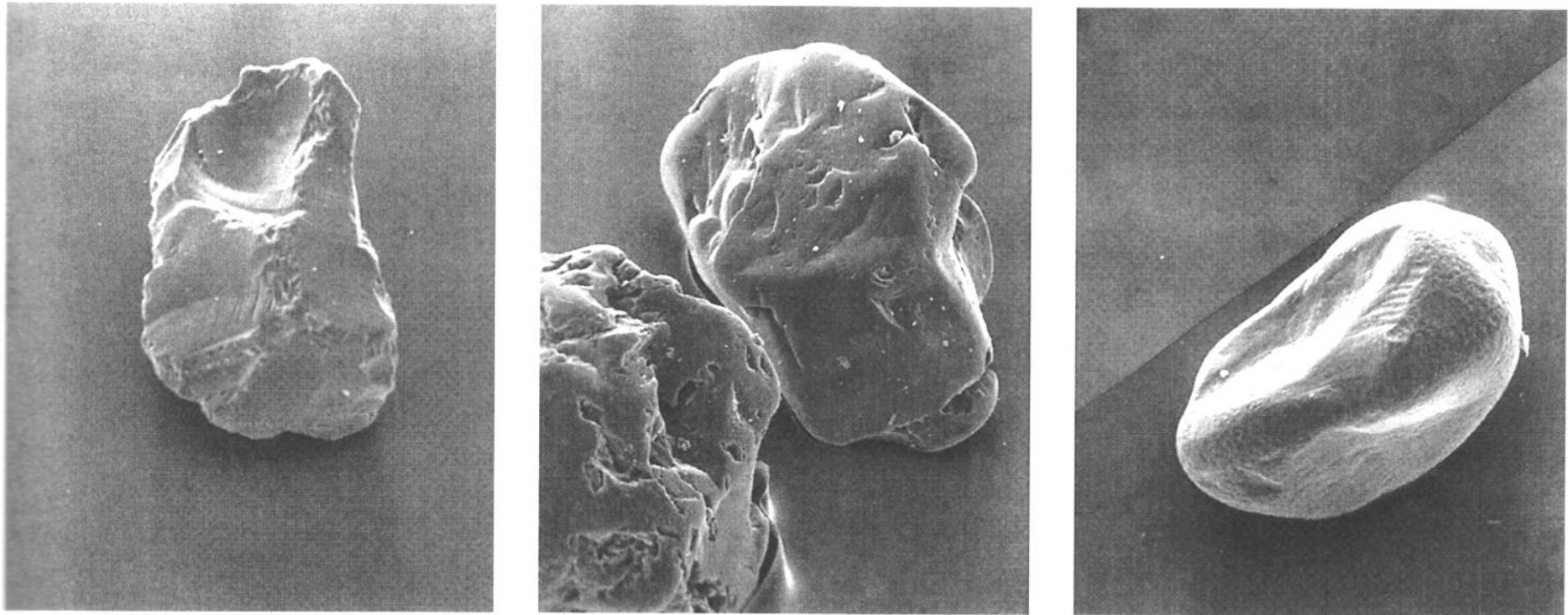
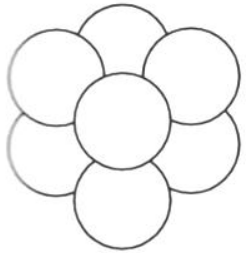


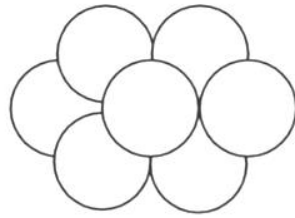
Fig. 2.7 Scanning electron micrographs of quartz sand grains from three modern environments. (a) Grain from glacial outwash deposit, Ottawa, Canada, showing conchoidal fractures and angular shape. (b) Grain from high-energy beach, Sierra Leone, West Africa, showing rounded shape and smooth surface with

small v-shaped percussion marks. (c) Grain from desert sand sea, Saudi Arabia, showing frosted, pock-marked surface (as a result of upturned plates, which are visible at higher magnifications) and conchoidal fractures resulting from mechanical chipping.

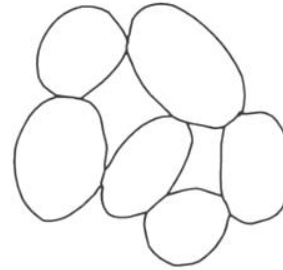
prostorové uspořádání zrn



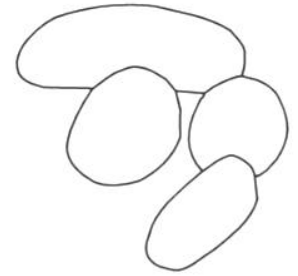
(a) Cubic packing
(48% porosity)



(b) Rhombohedral packing
(26% porosity)



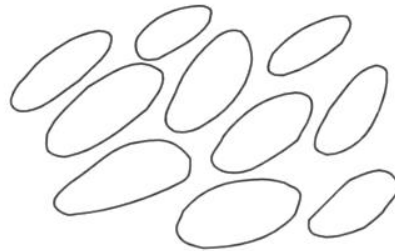
(c) Point contacts



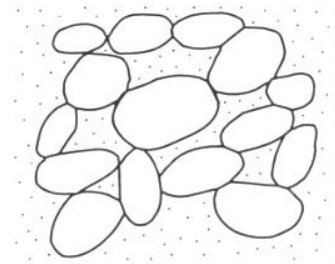
(d) Concavo-convex
contacts



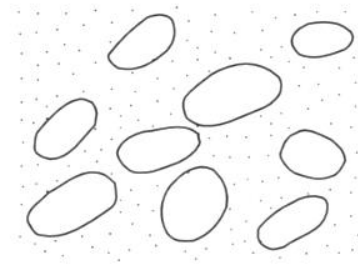
(e) Sutured contacts



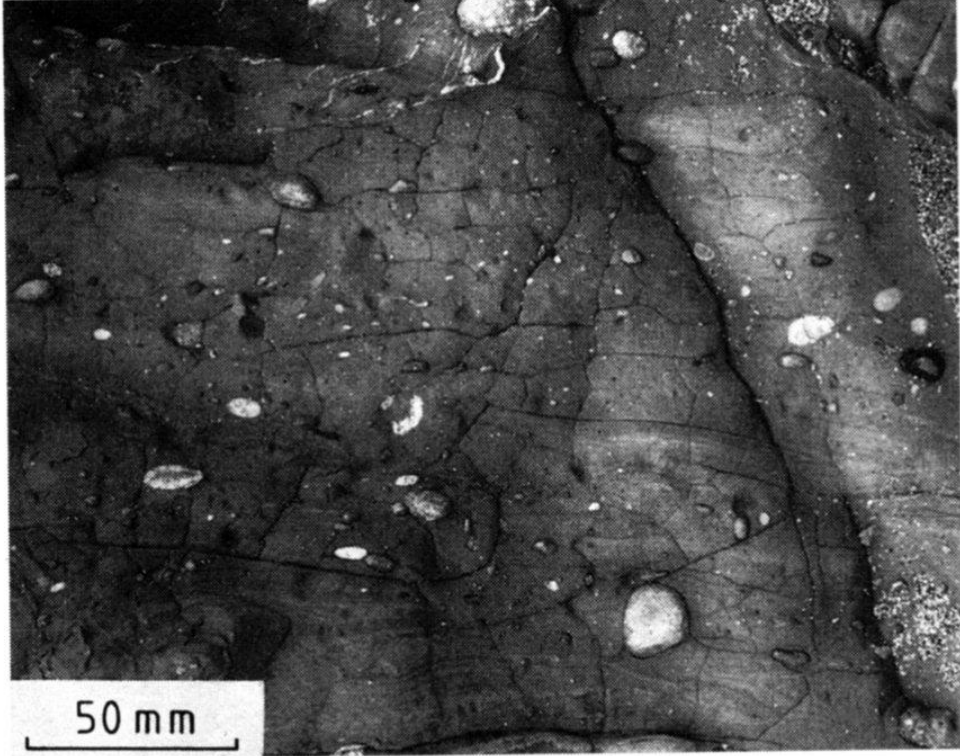
(f) Preferred orientation
of grains



(g) Grain-supported
fabric



(h) Matrix-supported
fabric



podpůrná stavba matrix

Fig. 2.9 Matrix-support fabric: pebbles 'float' in matrix. Notice also subtle synsedimentary folds. Tertiary deep-water pebbly mudstone of debris-flow origin. California, USA.



Fig. 2.10 Clast-support fabric; pebbles, mainly quartzite, are in contact and were deposited on a fan delta. Late Precambrian, Southern Norway.

podpůrná stavba zrn

sedimentační prostředí

kontinentální - aluviální vějíře, vějířové delty, fluviální (divočící, meandrující řeky), eolické, jezerní

delty (s dominantním vlivem řeky, vlnění, dmutí)

mořská - příbřežní (plážové písky, bariérové ostrovy, tidální plošiny),

předbřežní (hlubokovodní pánve, anoxie)

paleoproudová analýza

analýza provenience – studium původu (zdrojových hornin) klastického materiálu

modální složení

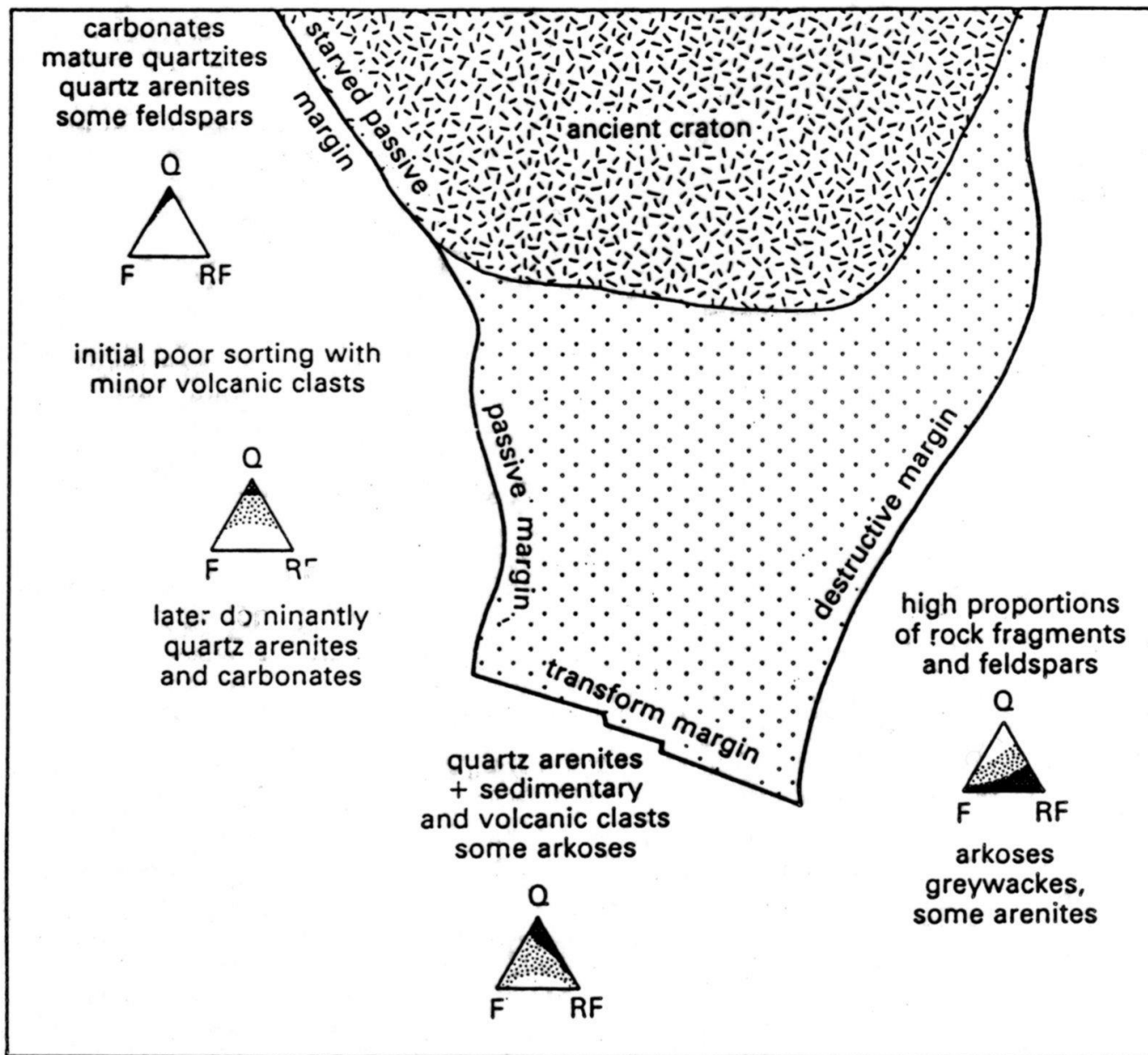


Fig. 5.10. Average modal compositions of groups of sandstones from different tectonic environments. This technique is only valid where many different sandstone modal compositions are available and cannot be used for single sandstone samples (modified from Folk, 1974b). Component details are documented in Table 5.5.

implikace: klima

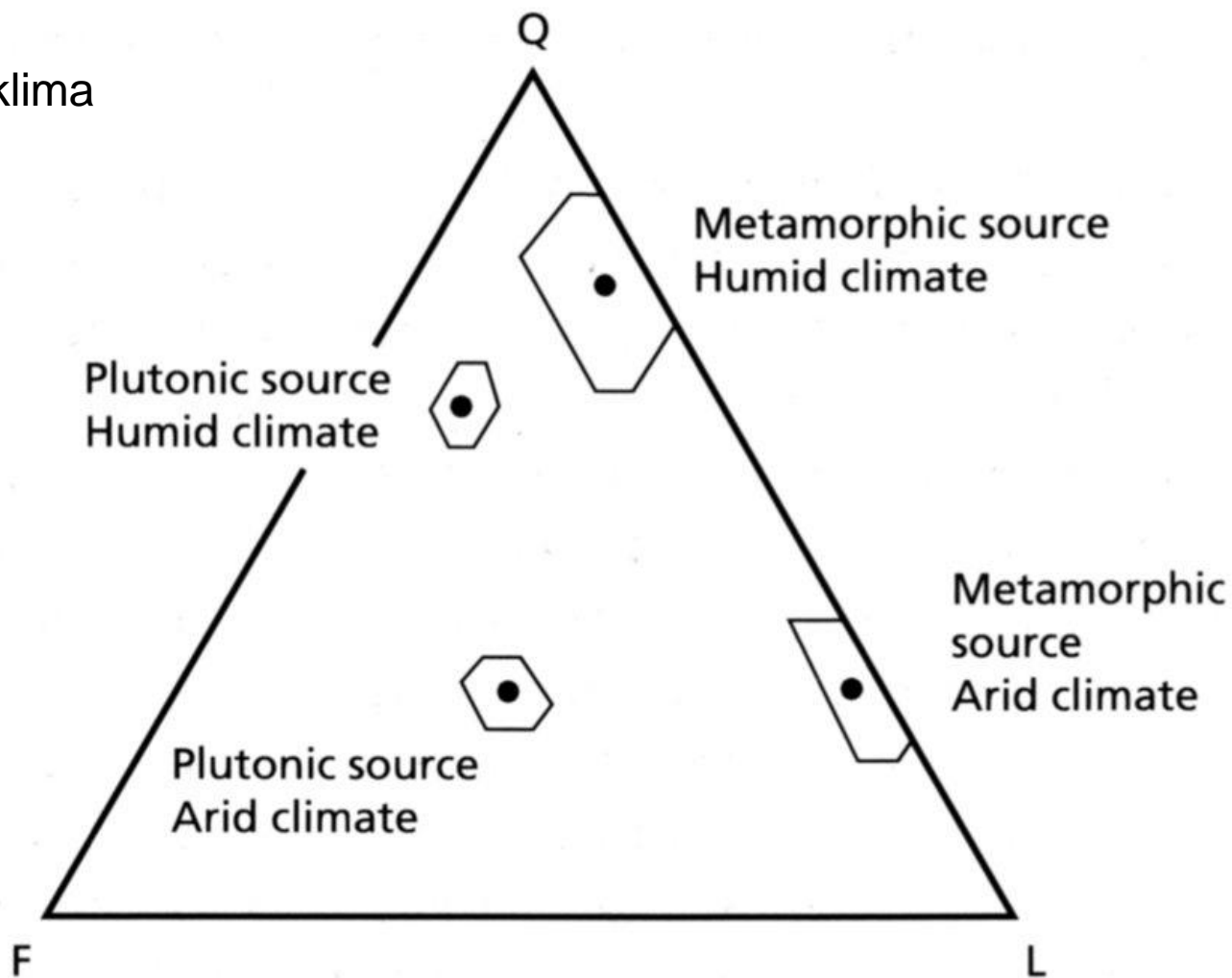


Fig. 2.46 Average compositions of medium sand-size fraction of first-cycle stream sediment derived from plutonic igneous and metamorphic sources under different climatic conditions. Q, quartz; F, feldspar; L, lithics.

implikace:
erozní trendy zdrojových oblastí

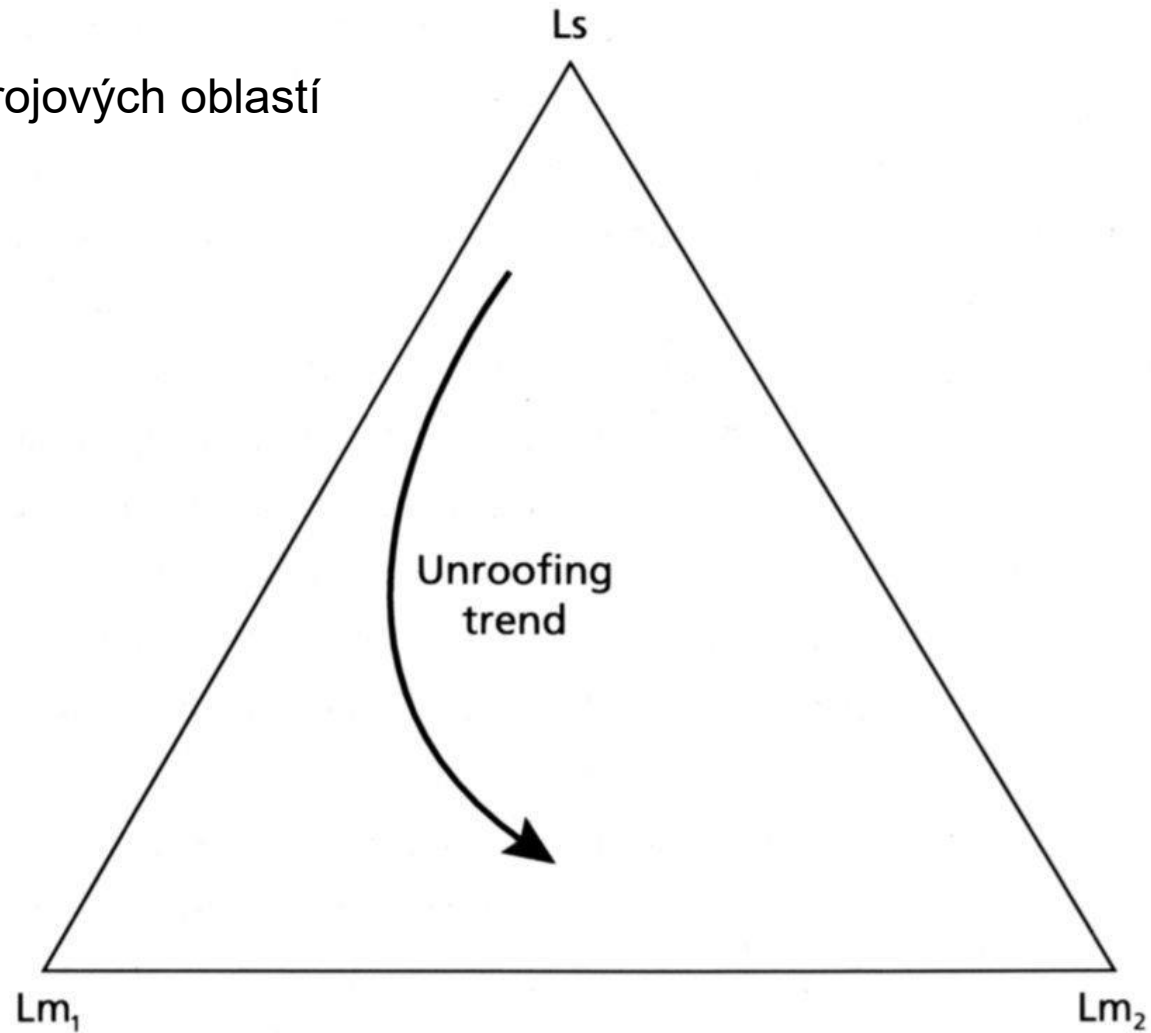
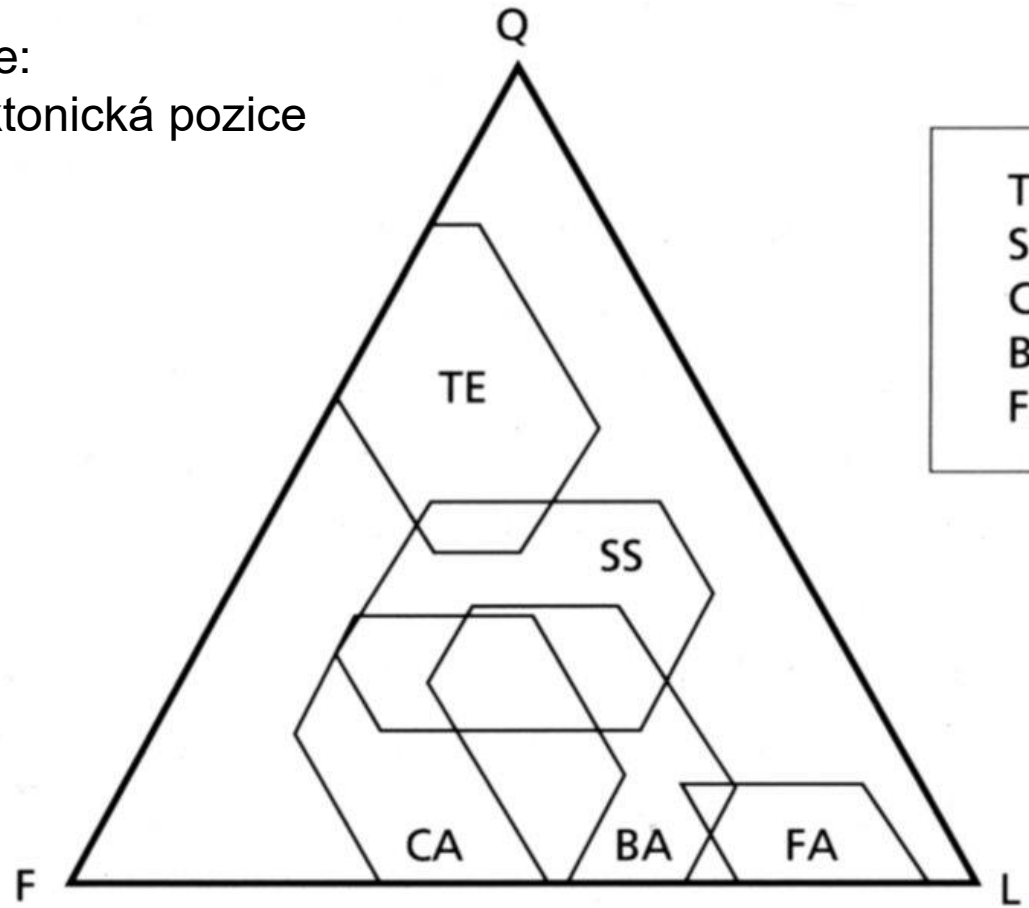
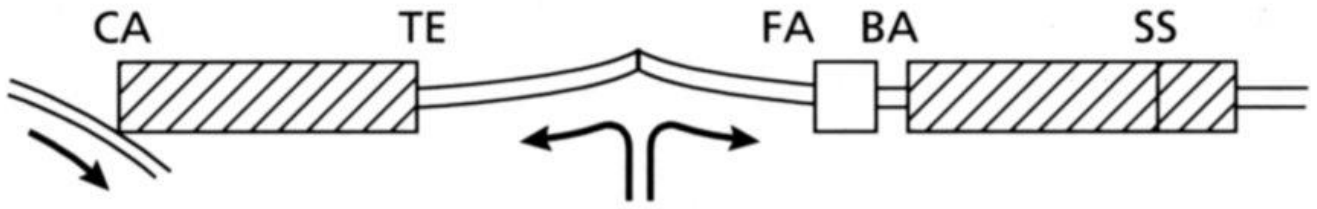


Fig. 2.47 The trend in lithic grains (Ls, sedimentary; Lm₁, low-grade metamorphic; Lm₂, medium-grade metamorphic) in sandstones derived from the unroofing of a sedimentary–metasedimentary complex of an arc–continent collision belt.

implikace:
geotektonická pozice



- TE : Passive margin
- SS : Strike-slip
- CA: Continental-margin arc
- BA: Back-arc to island arc
- FA: Fore-arc to island arc



těžké minerály (TM)








<p>Zircon $ZrSiO_4$ tetragonal</p> 	<p>colourless or pale, high relief & birefringence, parallel extinction</p>
<p>Tourmaline e.g. $NaFe_3B_3Al_3(OH)_4(Al_3Si_6O_{27})$ hexagonal</p> 	<p>pleochroic, brown, green, high relief, mod. birefringence, parallel extinction</p>
<p>Rutile TiO_2 tetragonal</p> 	<p>yellow-brown-red-opaque, v. high relief & birefringence, parallel extinction</p>
<p>Apatite $Ca_5(PO_4)_3F$ hexagonal</p> 	<p>colourless, moderate relief, weak birefringence, parallel extinction</p>
<p>Garnet e.g. $Fe_3Al_2(SiO_4)_3$ cubic</p> 	<p>colourless, pale pink-brown, high relief, isotropic</p>
<p>Staurolite $2Al_2Si_2O_5.Fe(OH)_2$ orthorhombic</p> 	<p>yellow, pleochroic, high relief, low birefringence, parallel extinction</p>
<p>Epidote $Ca_2(Al,Fe)_3(OH)(SiO_4)_3$ monoclinic</p> 	<p>yellow-green pleochroic, high relief, mod. birefringence, parallel extinction</p>

Fig. 2.55 Sketches of the seven most common heavy minerals (with the degree of weathering and or dissolution increasing to the right) together with their optical properties. After Füchtbauer (1974).

Table 4-2**Common Accessory Minerals in Sandstones and Types of Crystalline Rocks in Which They Usually Originate**

Igneous rocks	Metamorphic rocks	Indeterminate ^a
Aegerine	Actinolite	Enstatite
Augite	Andalusite	Hornblende
Chromite	Chloritoid	Hypersthene
Ilmenite	Cordierite	Magnetite
Olivine	Diopside	Sphene
Topaz	Epidote	Tourmaline
	Garnet	Zircon
	Glaucophane	
	Kyanite	
	Jadeite	
	Rutile	
	Sillimanite	
	Staurolite	
	Tremolite	
	Wollastonite	

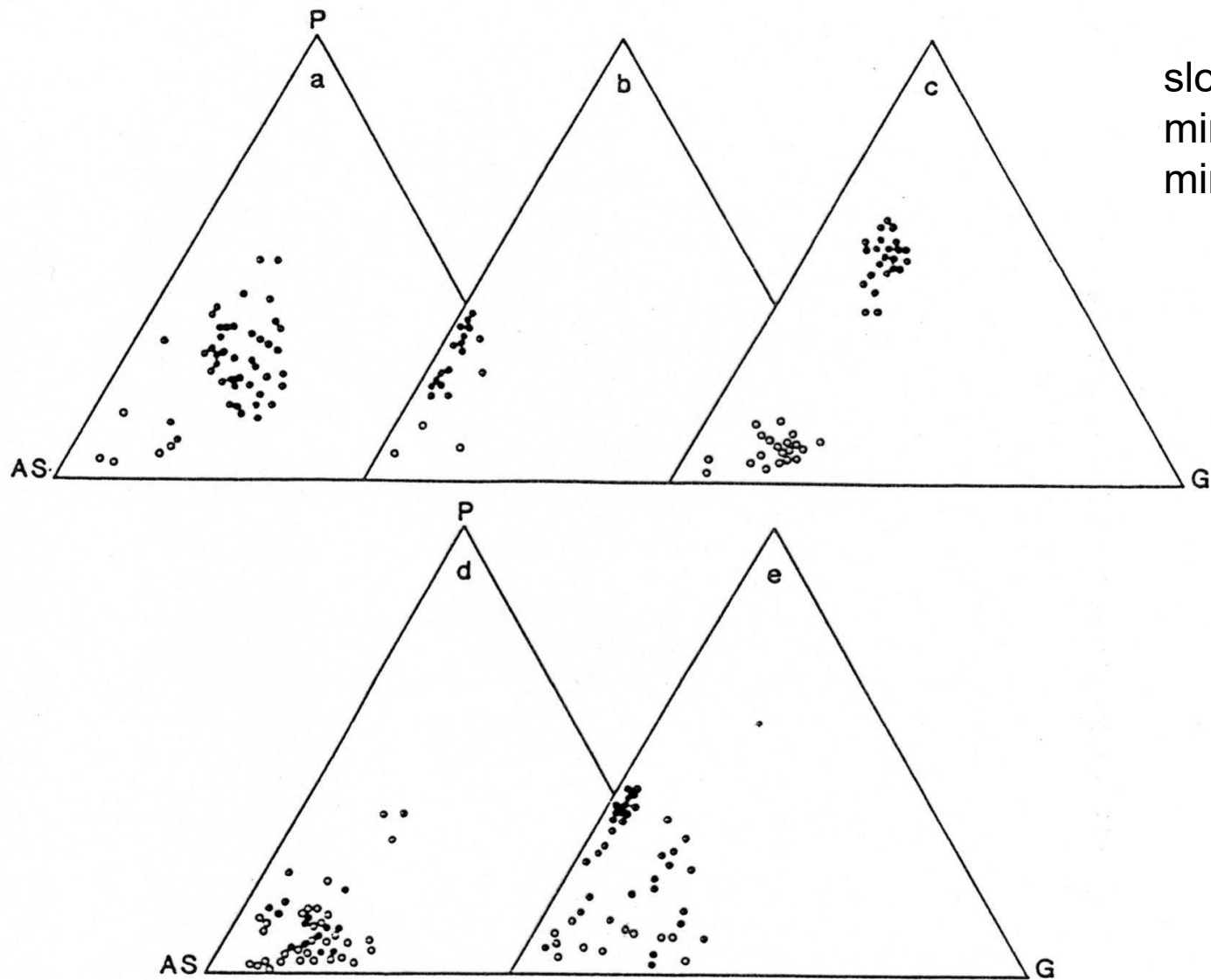
^a Common in both igneous and metamorphic rocks.

Table 8-3. *Stability of some detrital heavy minerals*

<i>Ultrastable</i>	Rutile, zircon, tourmaline, anatase
<i>Stable</i>	Apatite, garnet (iron-poor), staurolite, monazite, biotite, ilmenite, magnetite
<i>Moderately stable</i>	Epidote, kyanite, garnet (iron-rich), sillimanite, sphene, zoisite
<i>Unstable</i>	Hornblende, actinolite, augite, diopside, hypersthene, andalusite
<i>Very unstable</i>	Olivine

faktory ovlivňující zachování těžkých minerálů v sedimentárním záznamu:

- zvětrávání, eroze
- transport a sedimentace (hydraulické vlastnosti)
- expozice/zvětrávání na aluviální plošině
- diagenese (kompakce, působení pánevních/konátních vod)
- zvětrávání na výchoze



složení (chemismus/
mineralogie) těžkých
minerálů

Fig. 10. Illustration of the variety of compositions shown by detrital garnets of North Sea sediments. (a) Oseberg Formation (Middle Jurassic), Oseberg Field (from Hurst & Morton 1988). (b) Broom Formation (Middle Jurassic), Murchison Field (from Morton 1985*b*). (c) Etive Formation (Middle Jurassic), Murchison Field (from Morton 1985*b*). (d) Ness Formation (Middle Jurassic), Oseberg Field (from Hurst & Morton 1988). (e) Forties formation (Palaeocene), Forties Field (from Morton 1987*b*). AS, almandine + spessartine; P, pyrope; g, grossular. Open circles have spessartine > 5%, closed circles have spessartine < 5%.

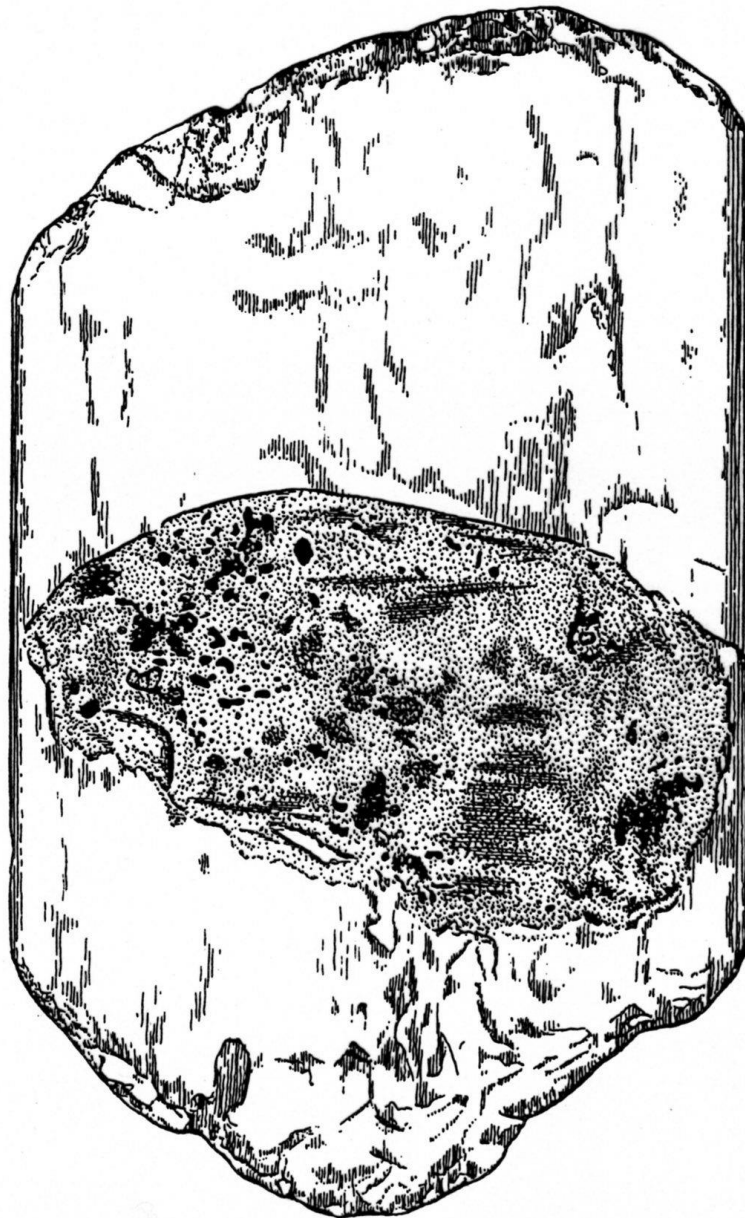
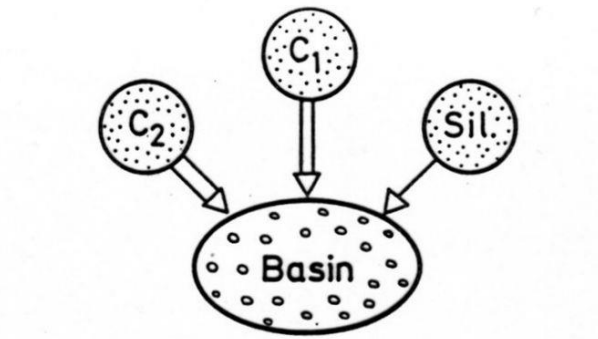
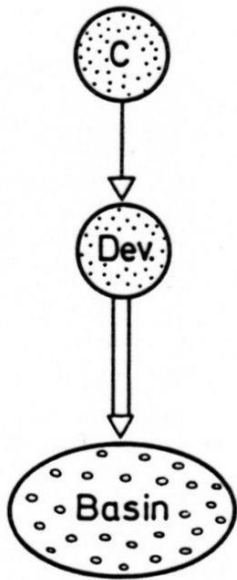


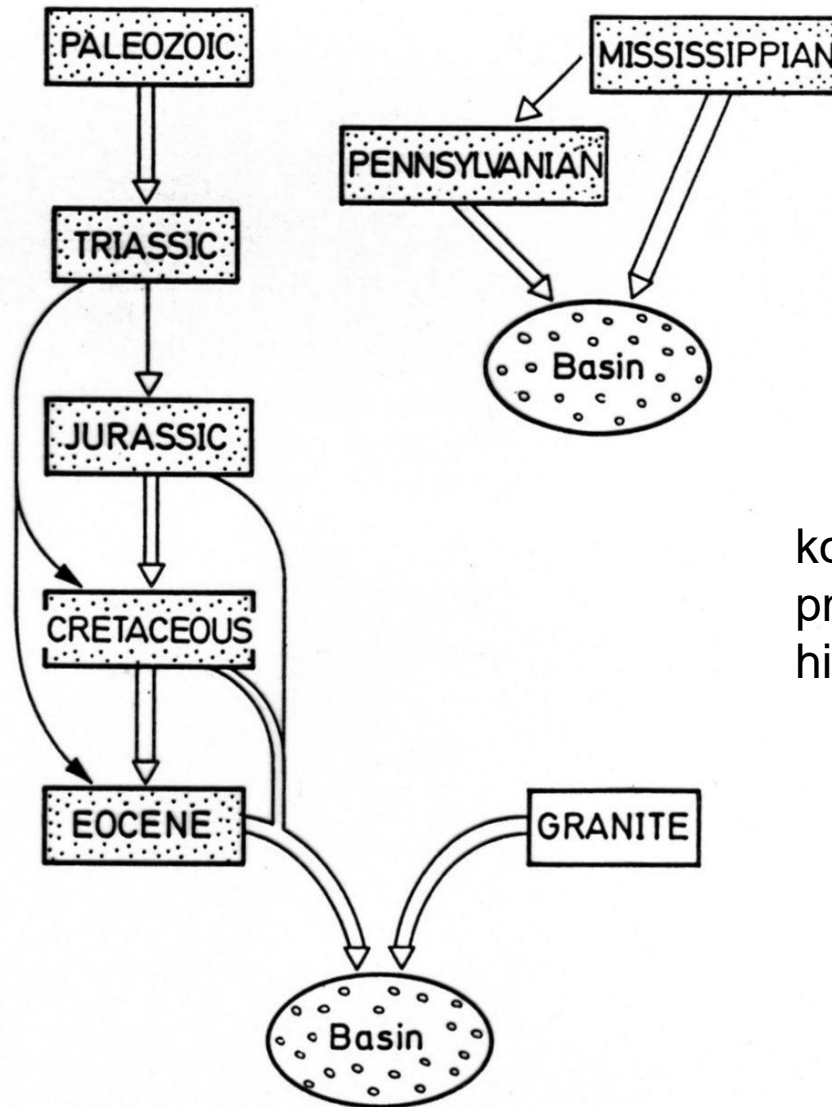
Fig. 8-3. Abraded tourmaline overgrowth on abraded detrital core, Cretaceous McNairy Sand, Henry County, Tennessee, U.S.A. (Redrawn from Potter and Pryor, 1961, Plate 2)



Direct Contributions from Geographically Distinct Sources



Progressive Recycling from Same Source



Recycling plus direct Contributions

komplexní
provenienční
historie

Fig. 8-8. Some common paths of mineral evolution

diagenese

geotermální gradient, termální modely

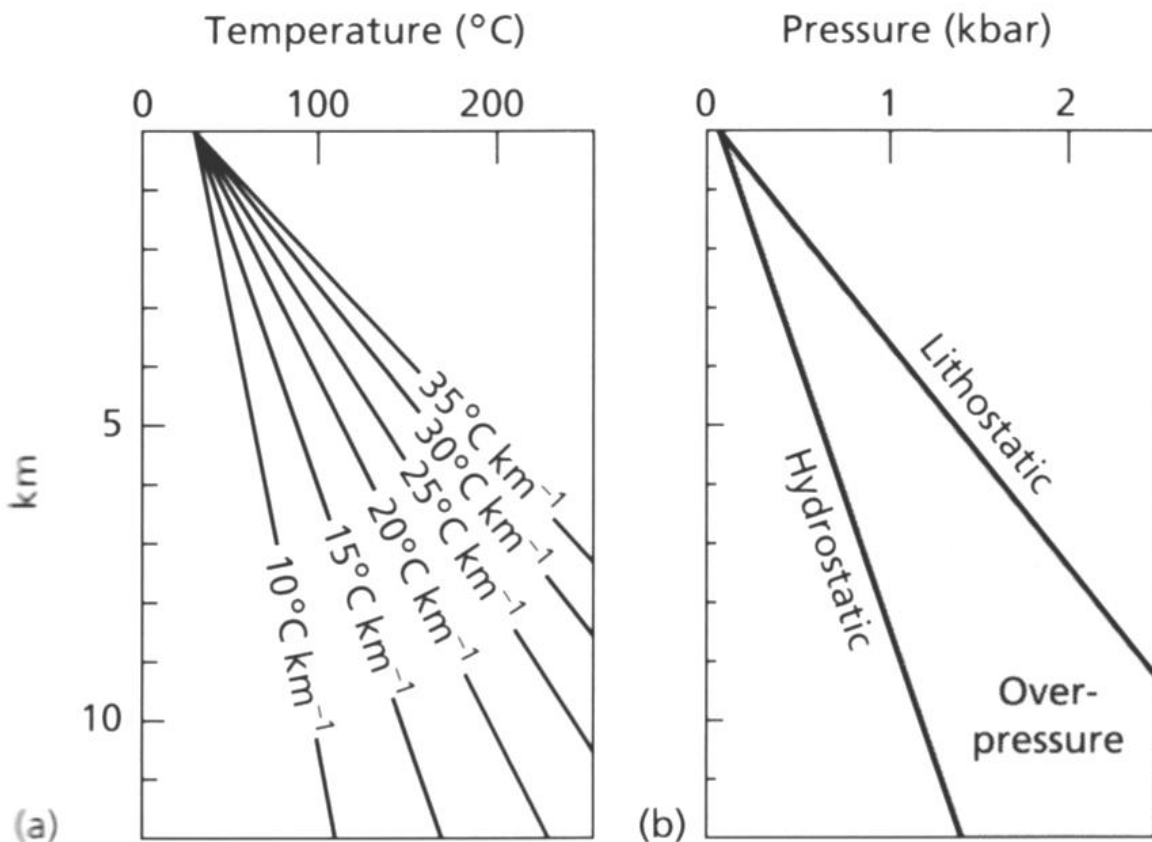
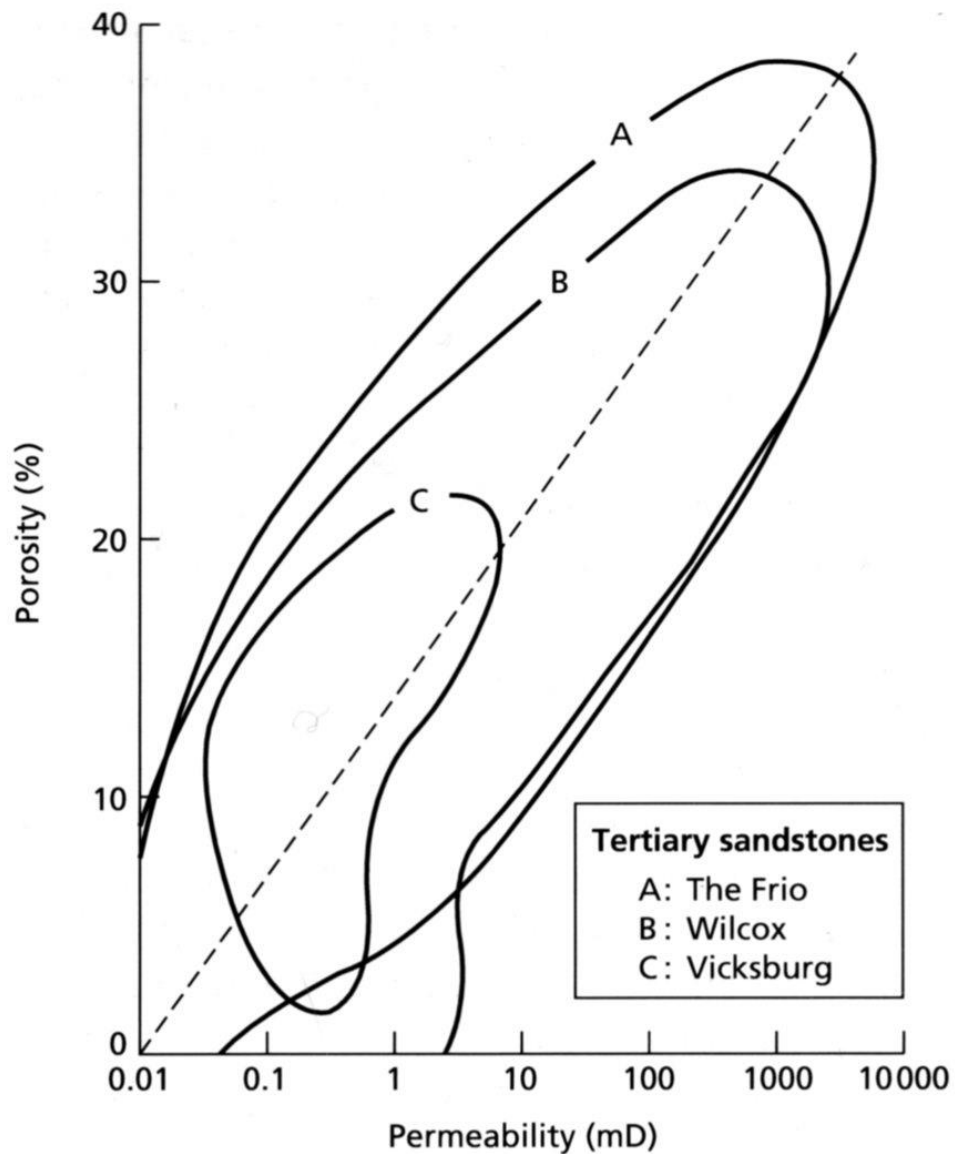


Fig. 2.53 (a) Increase in temperature with increasing depth for different geothermal gradients. (b) Increase in hydrostatic and lithostatic (overburden) pressure with increasing depth.



porozita, permeabilita

Fig. 2.59 Porosity–permeability plot for three Tertiary sandstones of the Gulf Coast subsurface, the Frio (a), Wilcox (b) and Vicksburg (c), showing the general increase in permeability with increasing porosity. After Loucks *et al.* (1984).

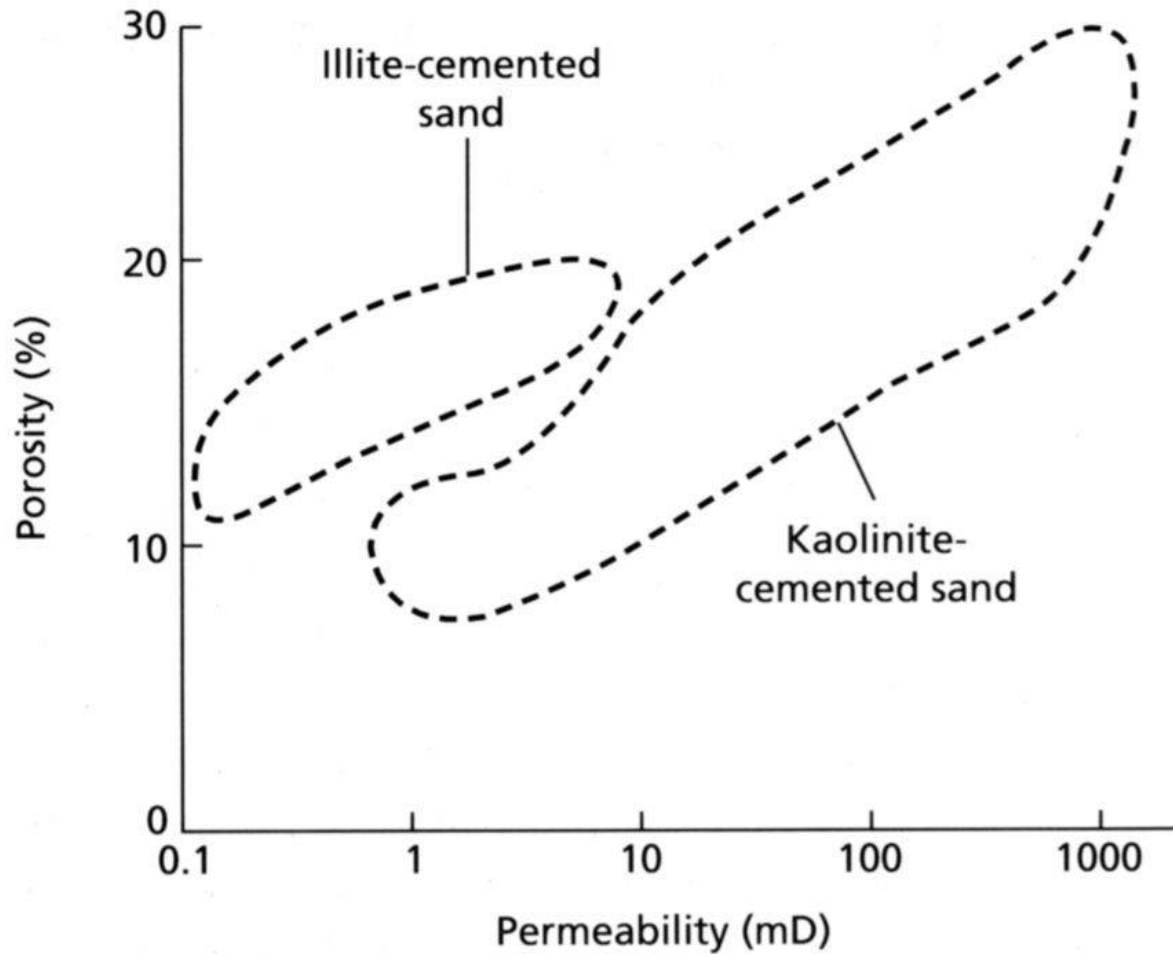


Fig. 2.56 Porosity–permeability plot for kaolinite- and illite-cemented aeolian sandstones in the Permian Rotliegendes. Southern North Sea. After Stalder (1973).

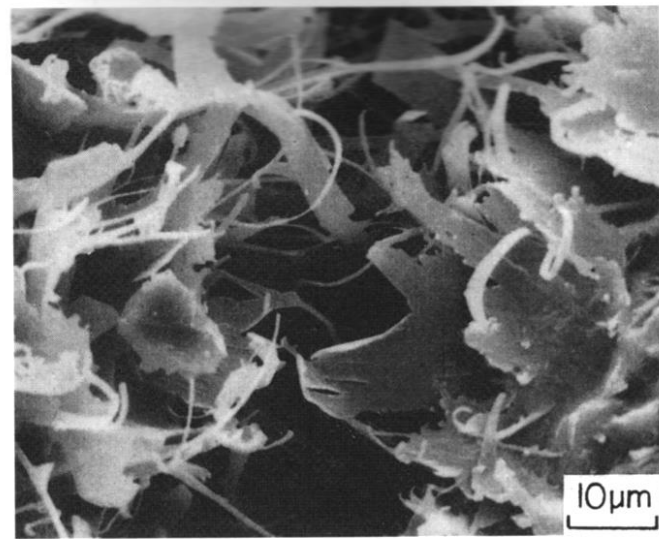


Fig. 2.54 Scanning electron micrograph of authigenic illite in the form of radially arranged flakes and whiskers growing into pore space between two sand grains (left and right of picture). Rotliegend desert sandstone, Lower Permian. Northern Germany.

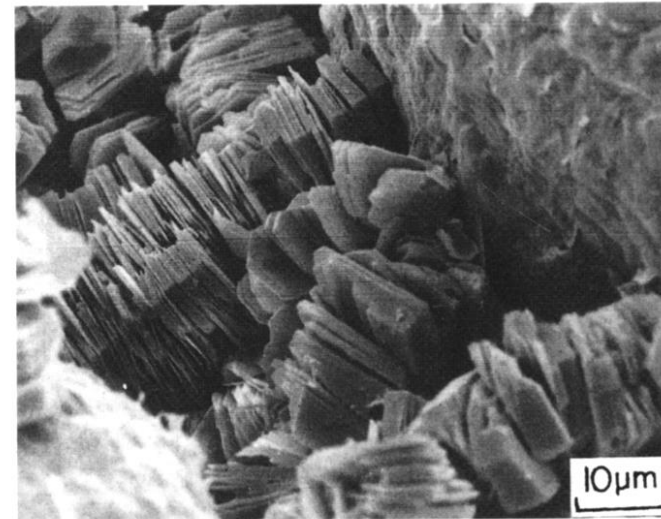


Fig. 2.55 Scanning electron micrograph of authigenic kaolinite, consisting of stacked pseudo-hexagonal platy crystals, between rounded sand grains. Rotliegend desert sandstone. Lower Permian. Northern Germany.

tmely - křemité (syntaxiální nárůsty)

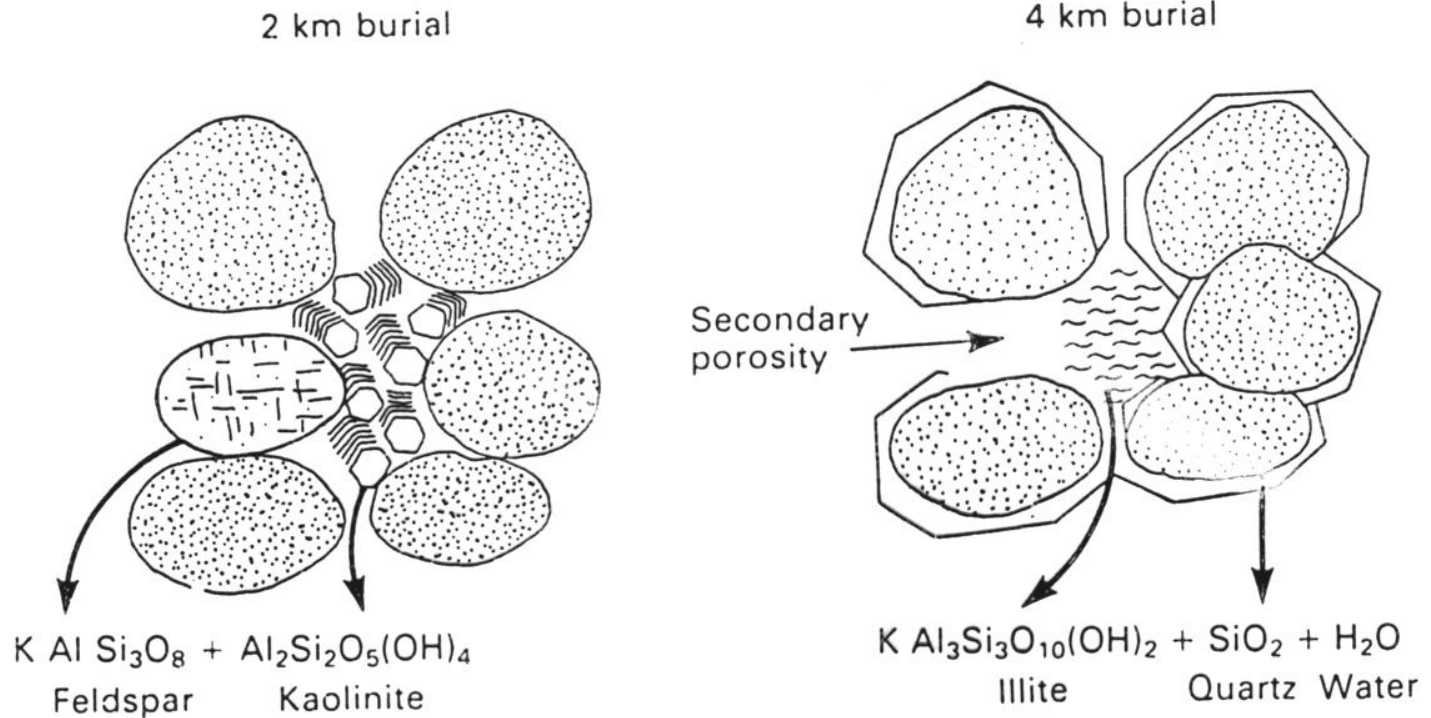


Fig. 5.28. Chemical reactions between feldspar and kaolinite are triggered by continued burial to produce illite, quartz overgrowth cements plus secondary porosity (from Bjørlykke, 1983).

kompakce
tlakové rozpouštění

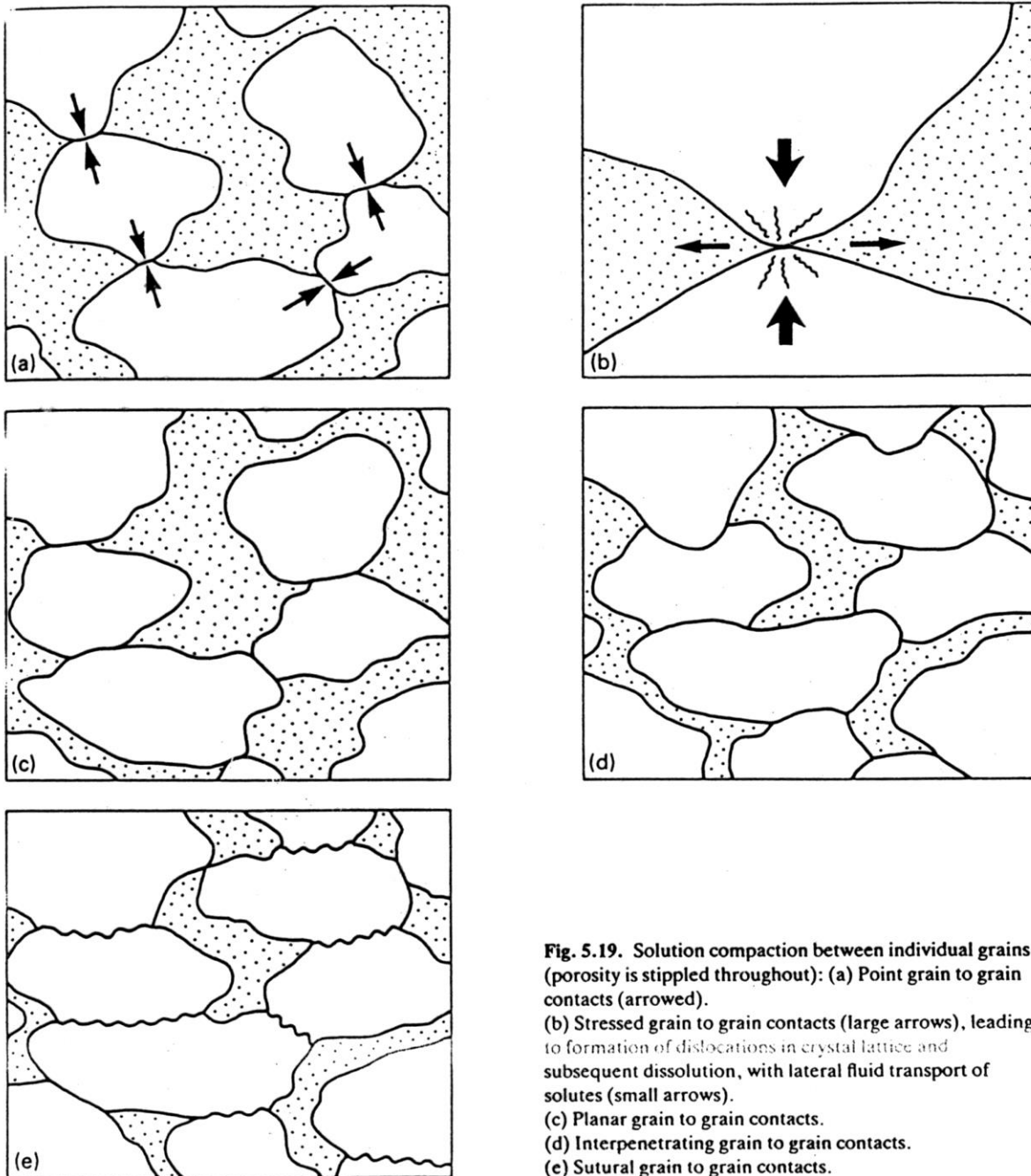
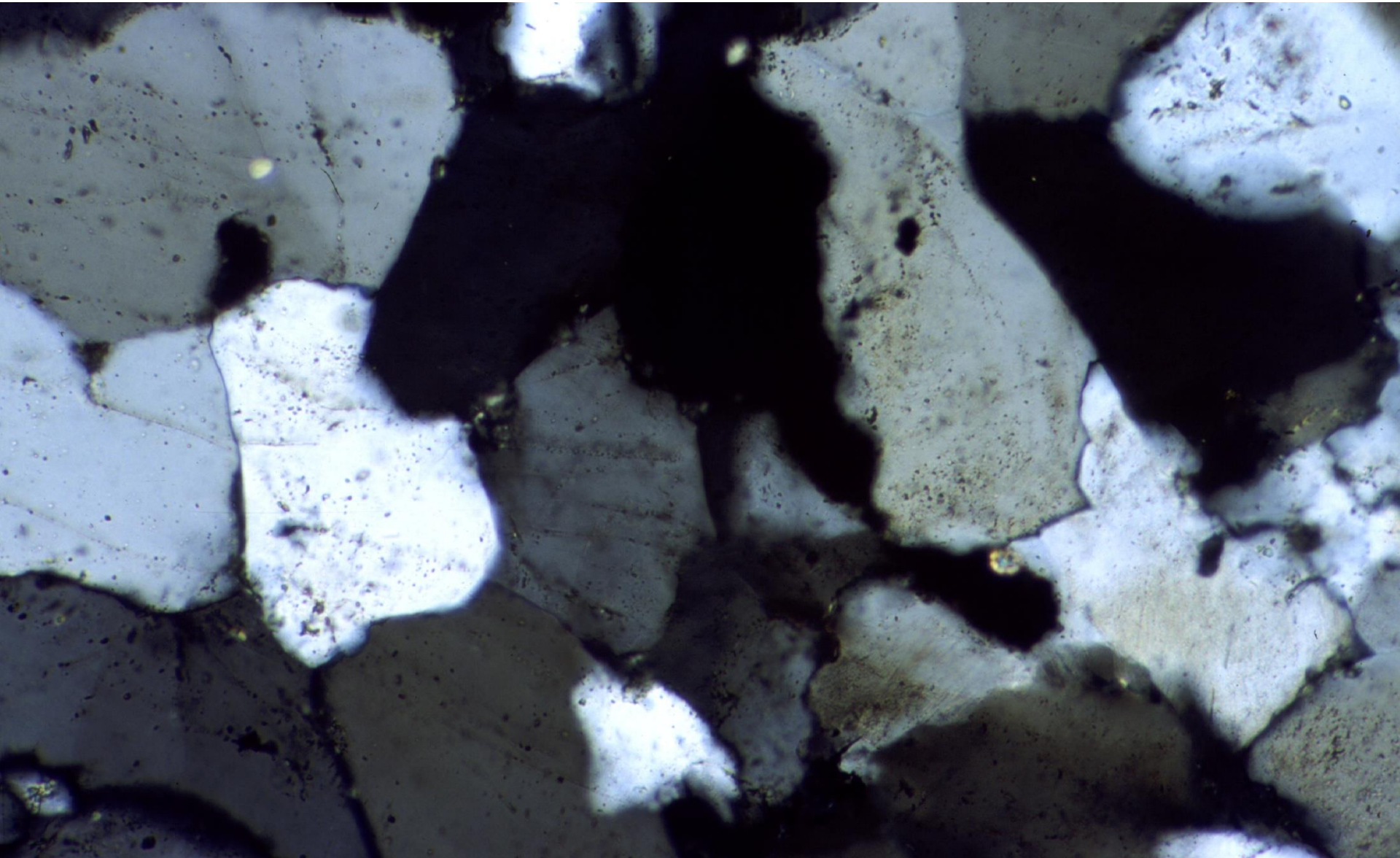
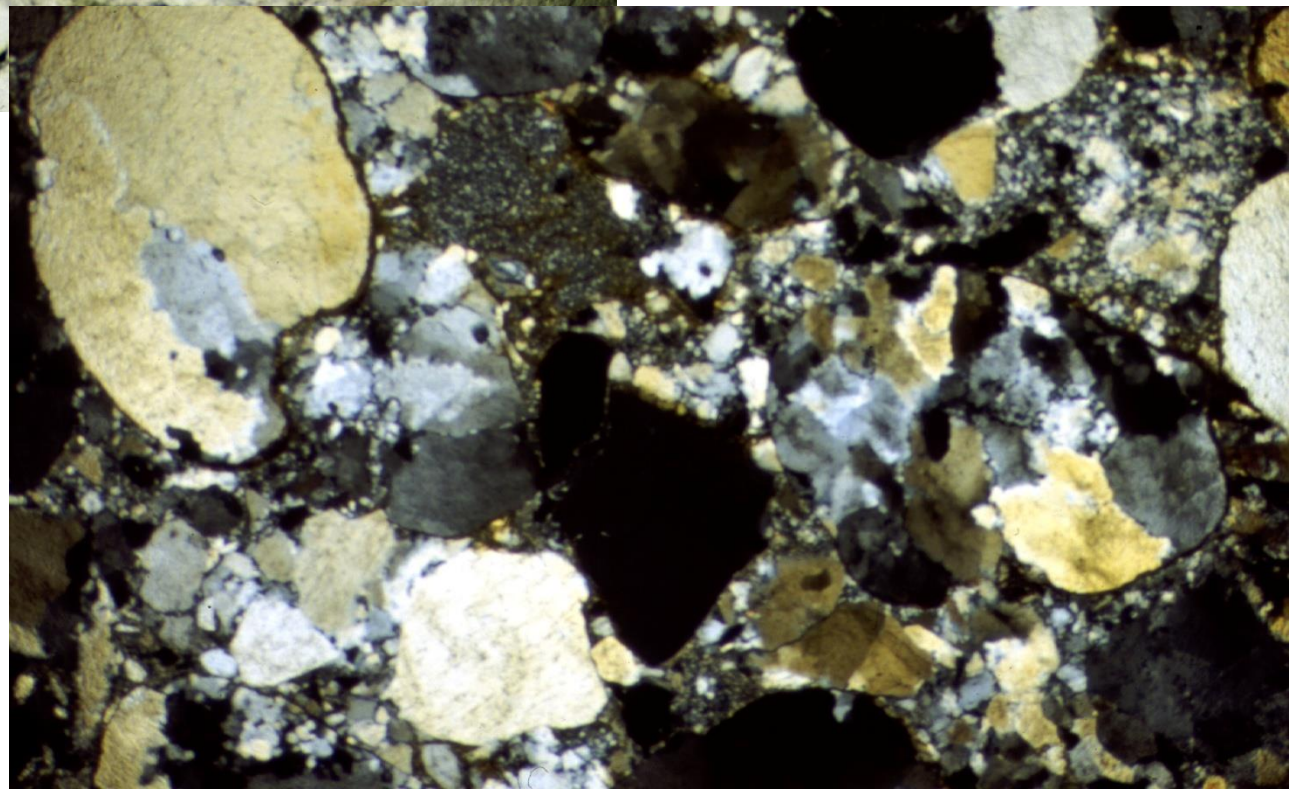
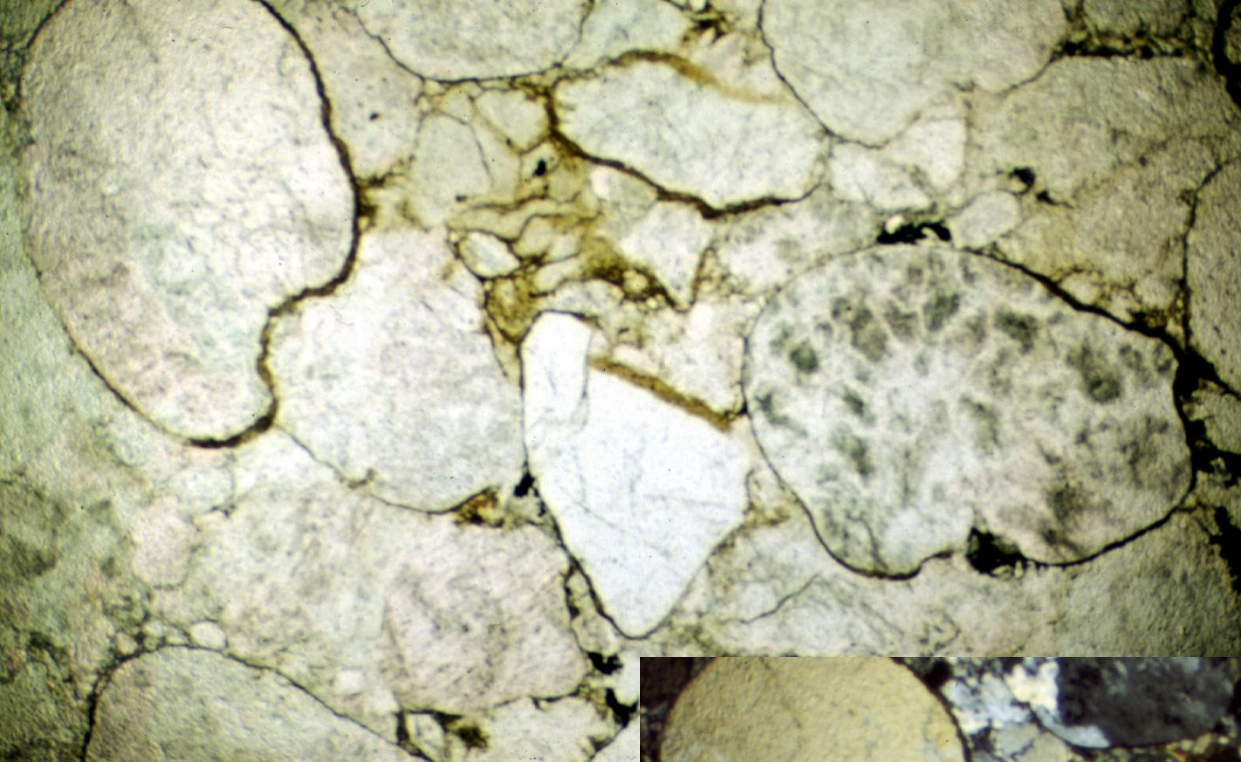
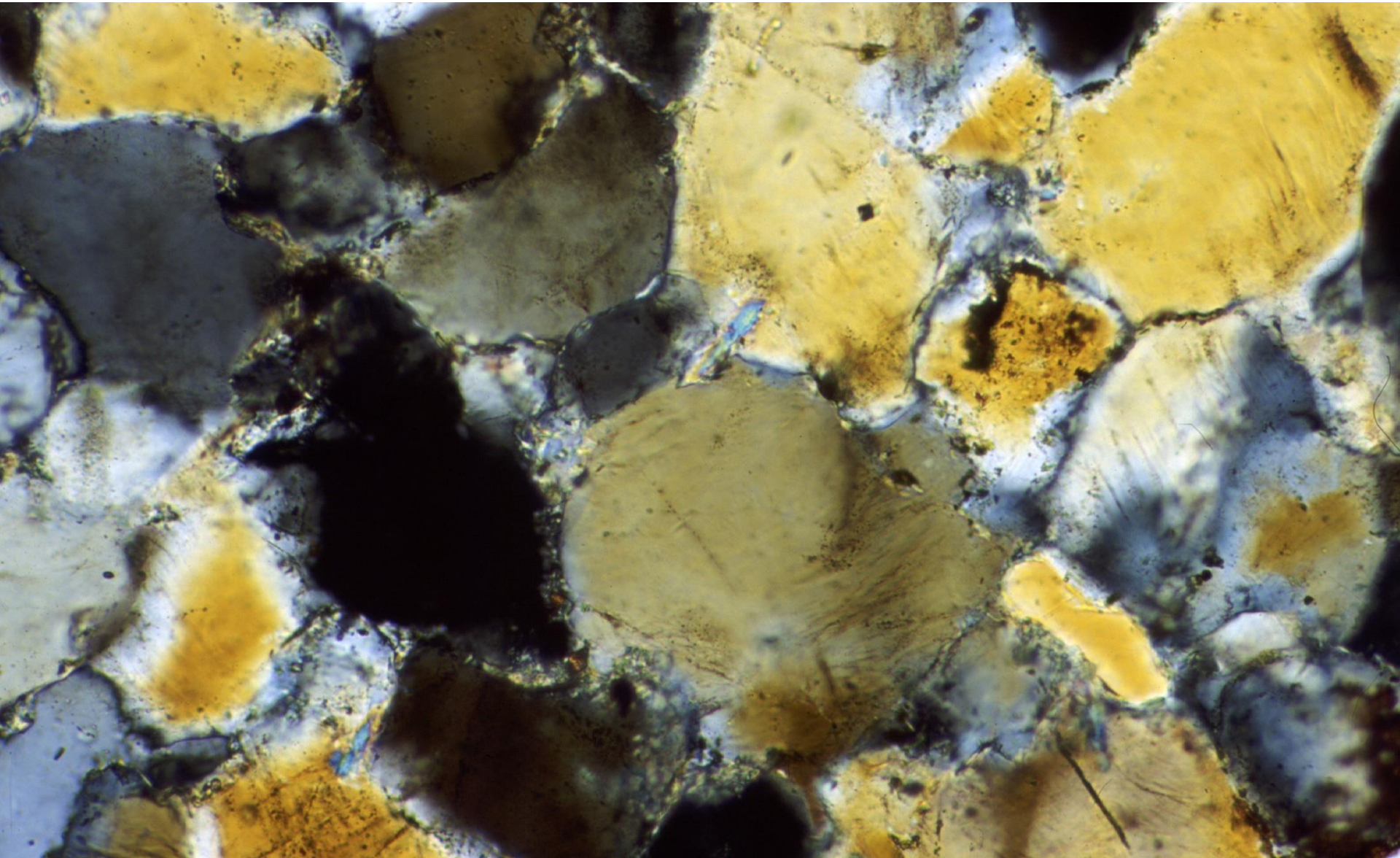
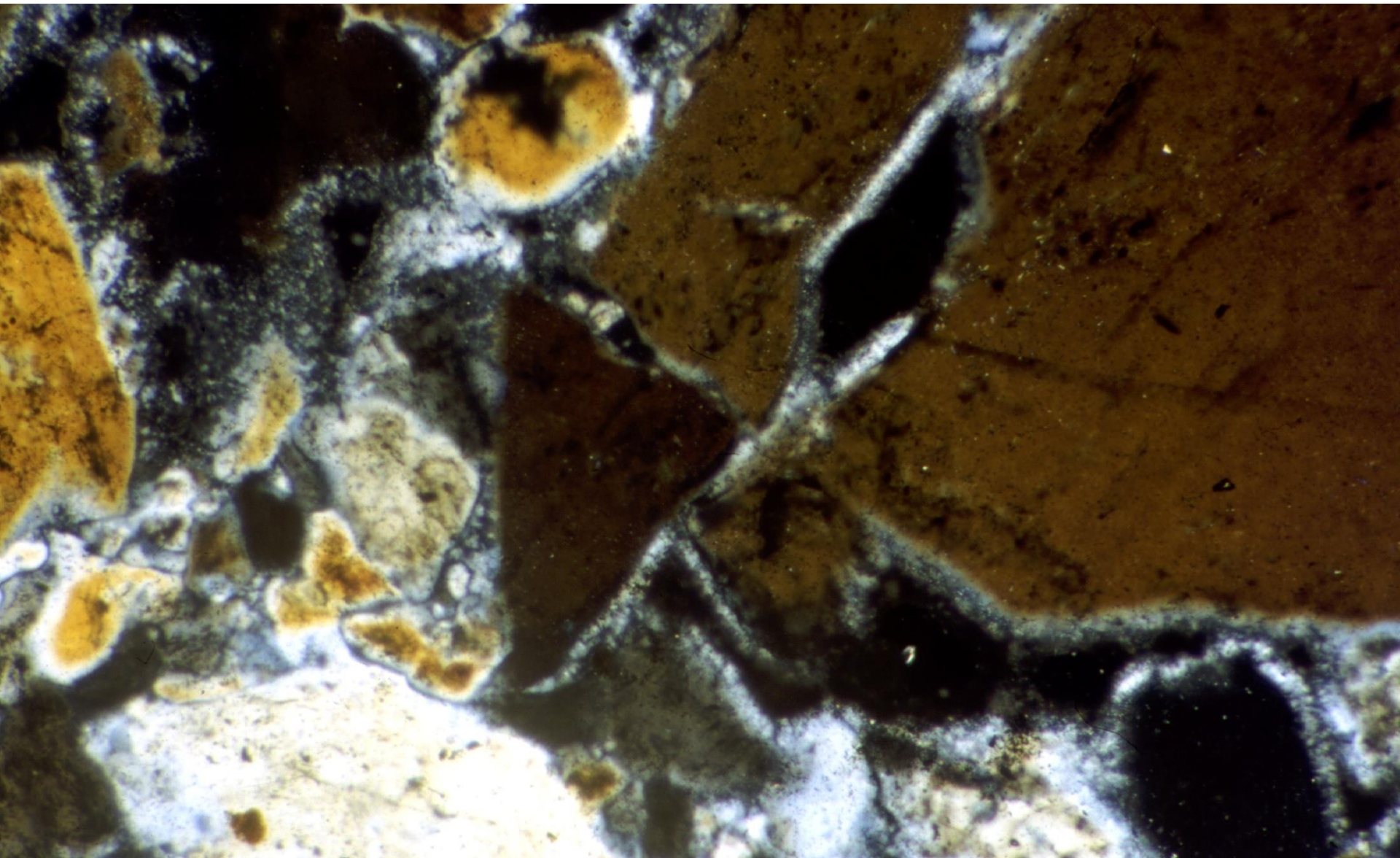


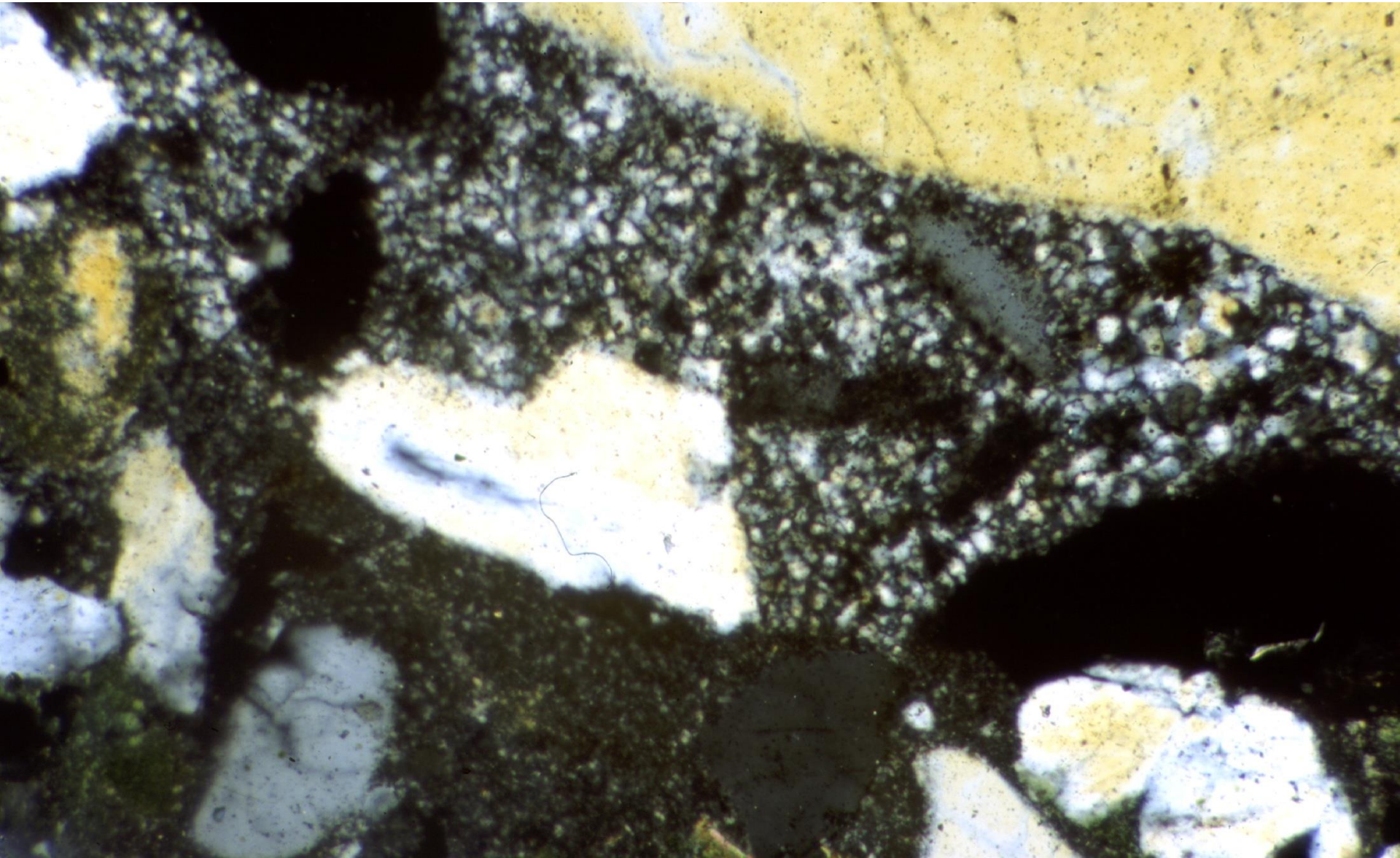
Fig. 5.19. Solution compaction between individual grains (porosity is stippled throughout): (a) Point grain to grain contacts (arrowed). (b) Stressed grain to grain contacts (large arrows), leading to formation of dislocations in crystal lattice and subsequent dissolution, with lateral fluid transport of solutes (small arrows). (c) Planar grain to grain contacts. (d) Interpenetrating grain to grain contacts. (e) Sutural grain to grain contacts.



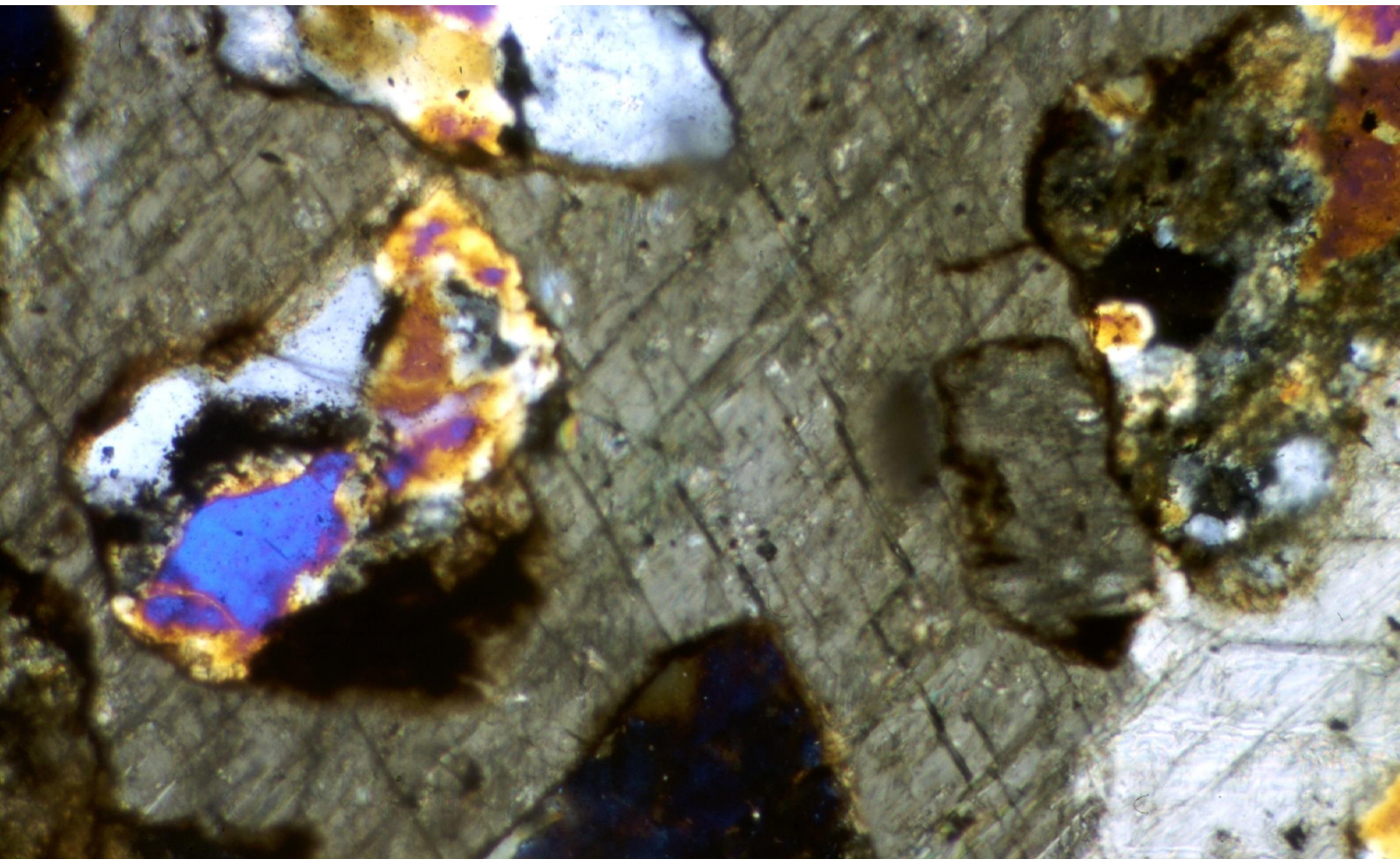








tmely - karbonátové



další diagenetické fenomény:

sekundární porozita

tmely - autigenní živce (nárůsty), jílní minerály a zeolity, hematit, baryt

vztah hloubky
pohřbení, kompakce
a porozity

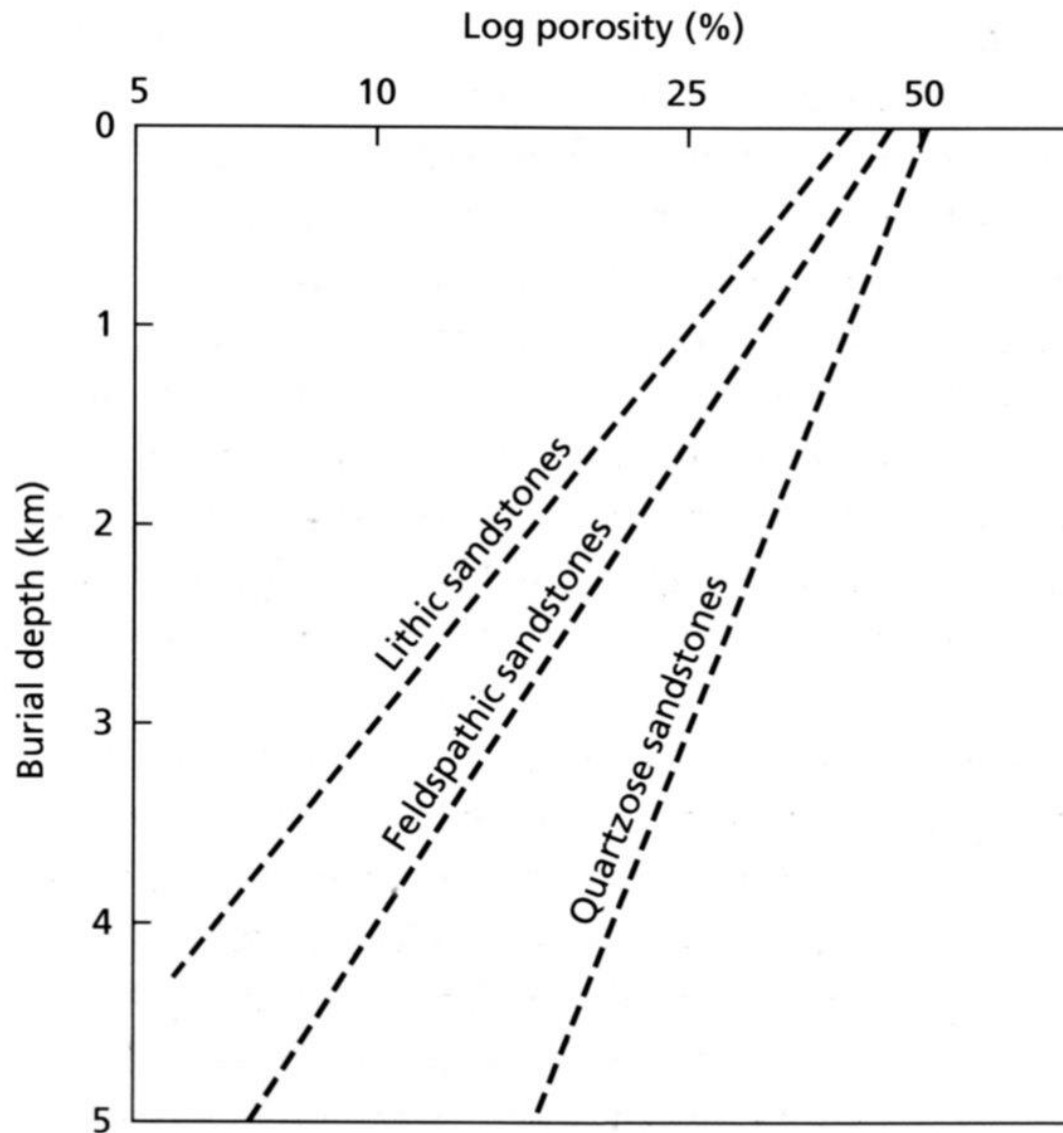
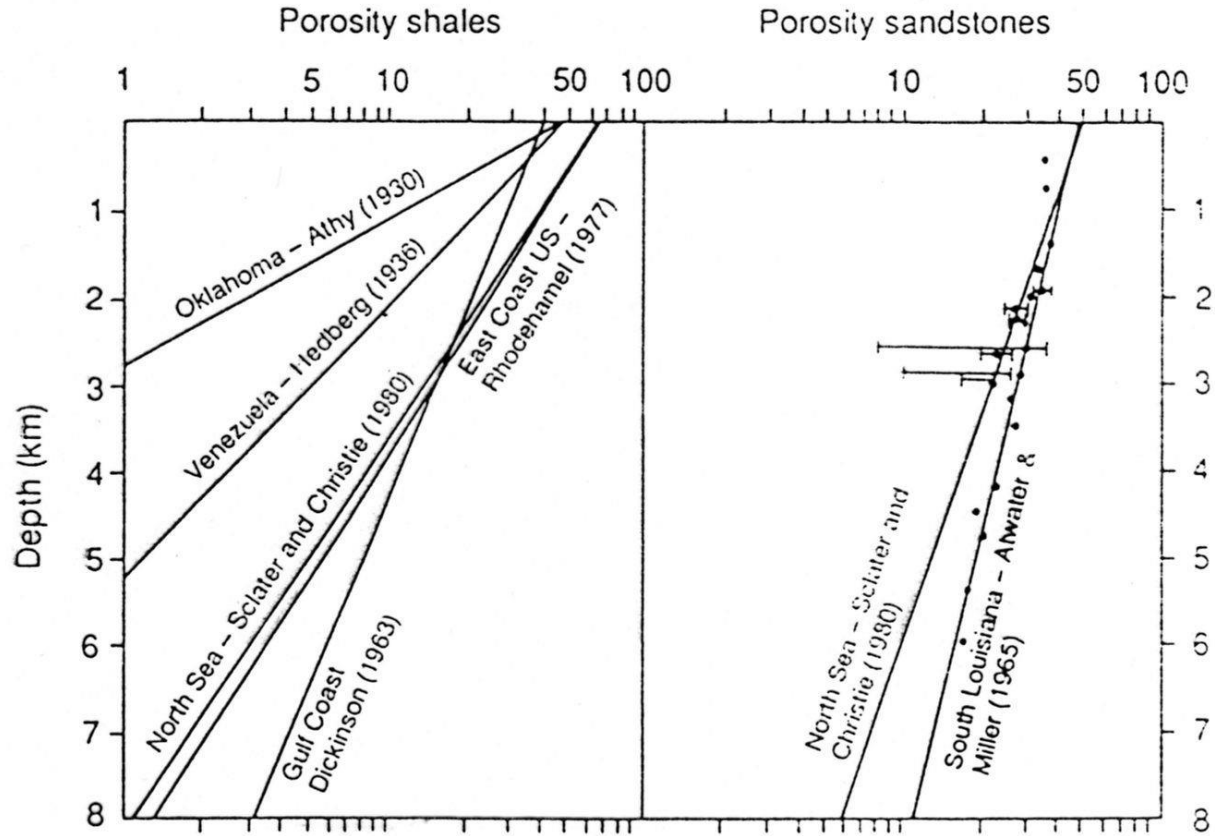


Fig. 2.60 Porosity–depth relationship for sandstones of different composition. After Dickinson (1985), based on several sources.

Fig. 8.2. Plots of log porosity against depth for shales and sandstones (after Sclater and Christie 1980). The North Sea shale data are from sonic log values in normally pressured sections, porosities being calculated from the sonic velocity/porosity relation proposed by Magara (1976). The North Sea sandstone data are from the data of Seeley (1978) supplemented by data from sonic logs. The best-fit lines for the North Sea data and for the south Louisiana data of Atwater and Miller (1965) are constrained to pass through the surface porosity values of Pryor (1973).



diagenetické trendy modálního složení

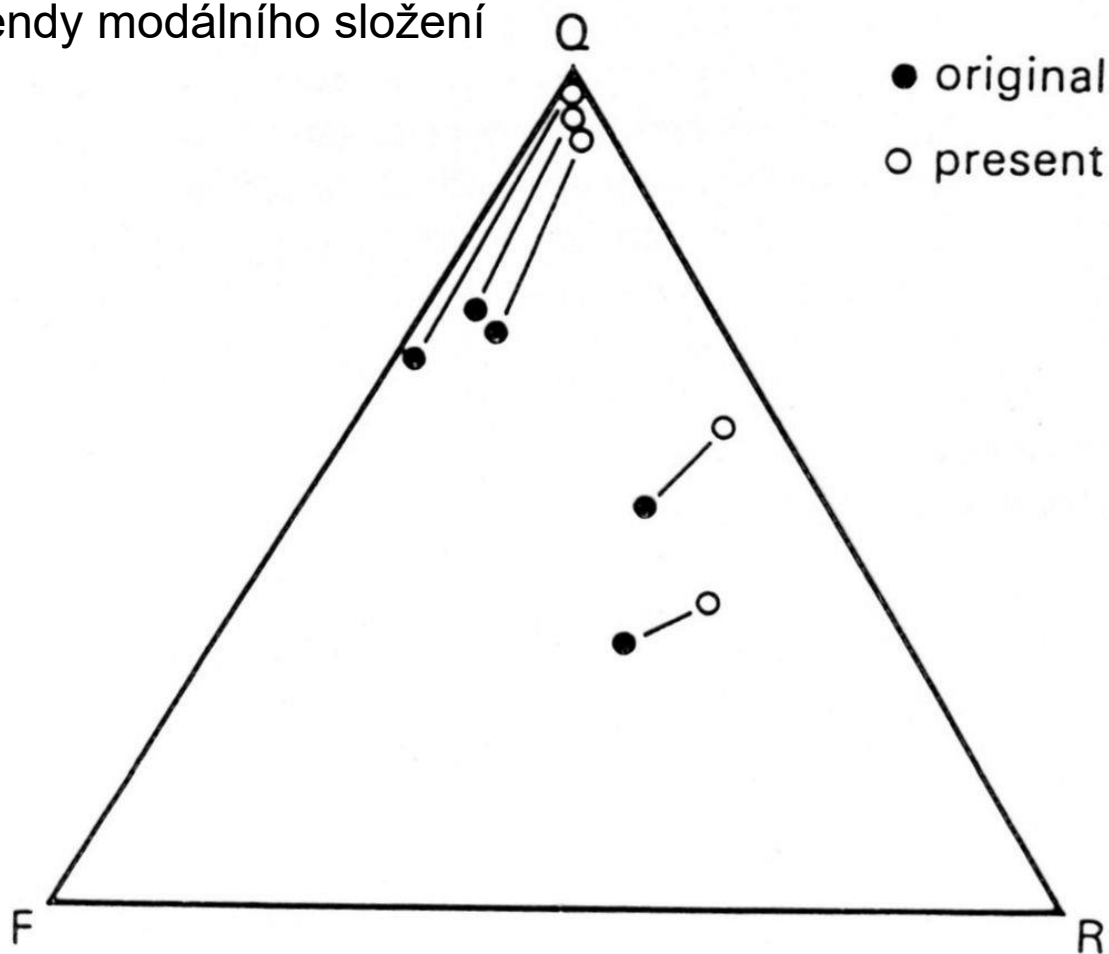
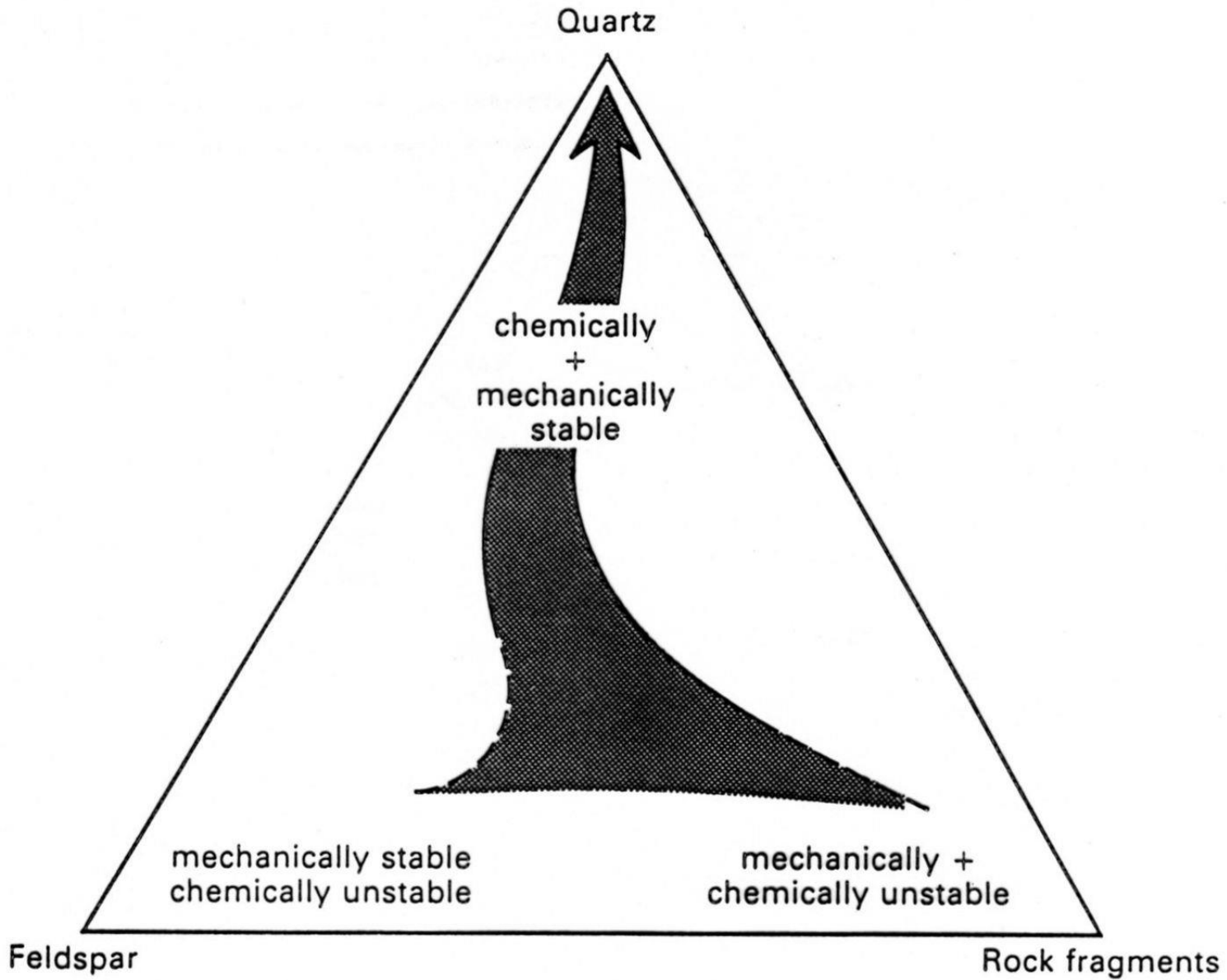


Fig. 5.37. Triangular diagram showing the present composition of five sandstones, after dissolution and alteration, and their reconstructed composition, assuming 15% of the grains which occupied oversized pores were rock fragments and 85% were feldspar (from McBride, 1985).



diagenetická prostředí

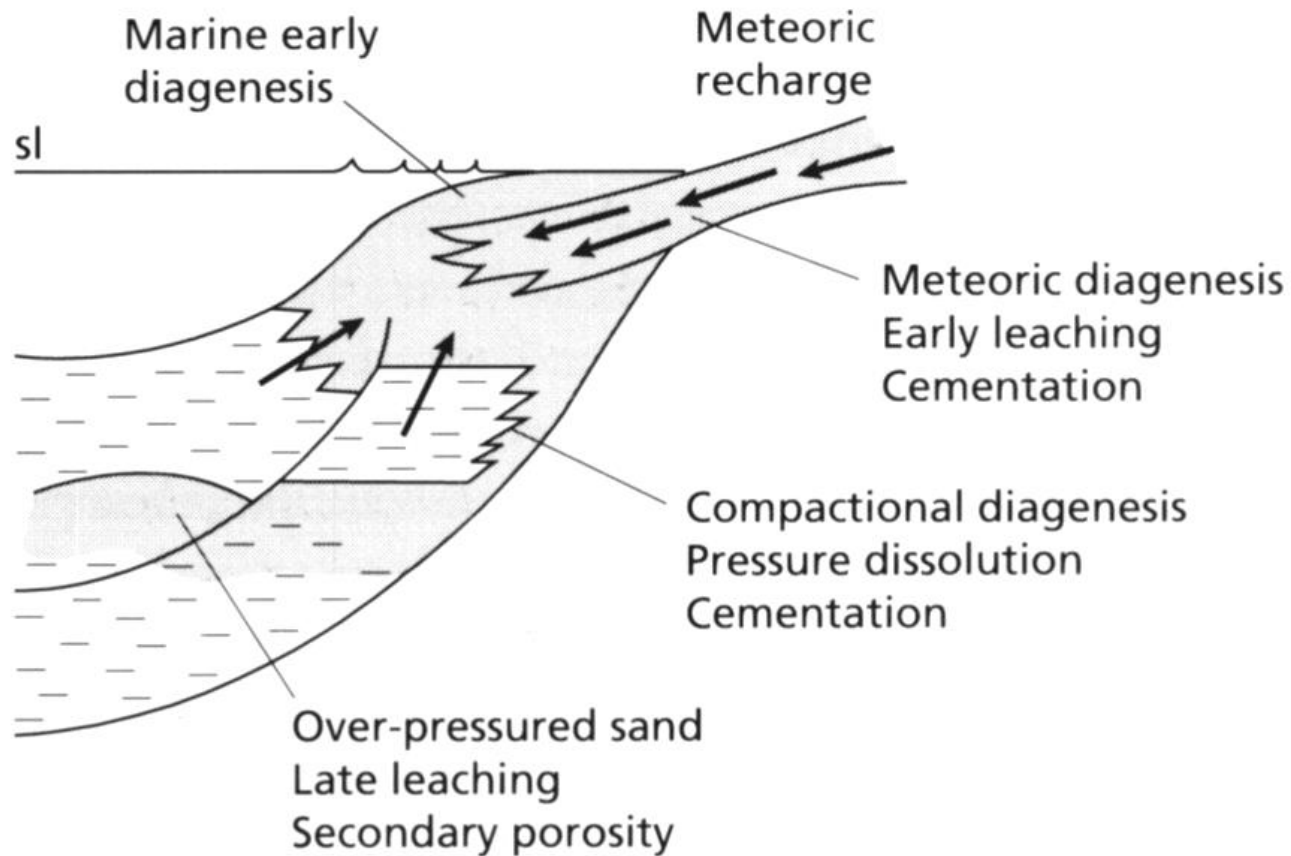


Fig. 2.57 Sketch illustrating main siliclastic diagenetic environments. After Bjørlykke (1988).

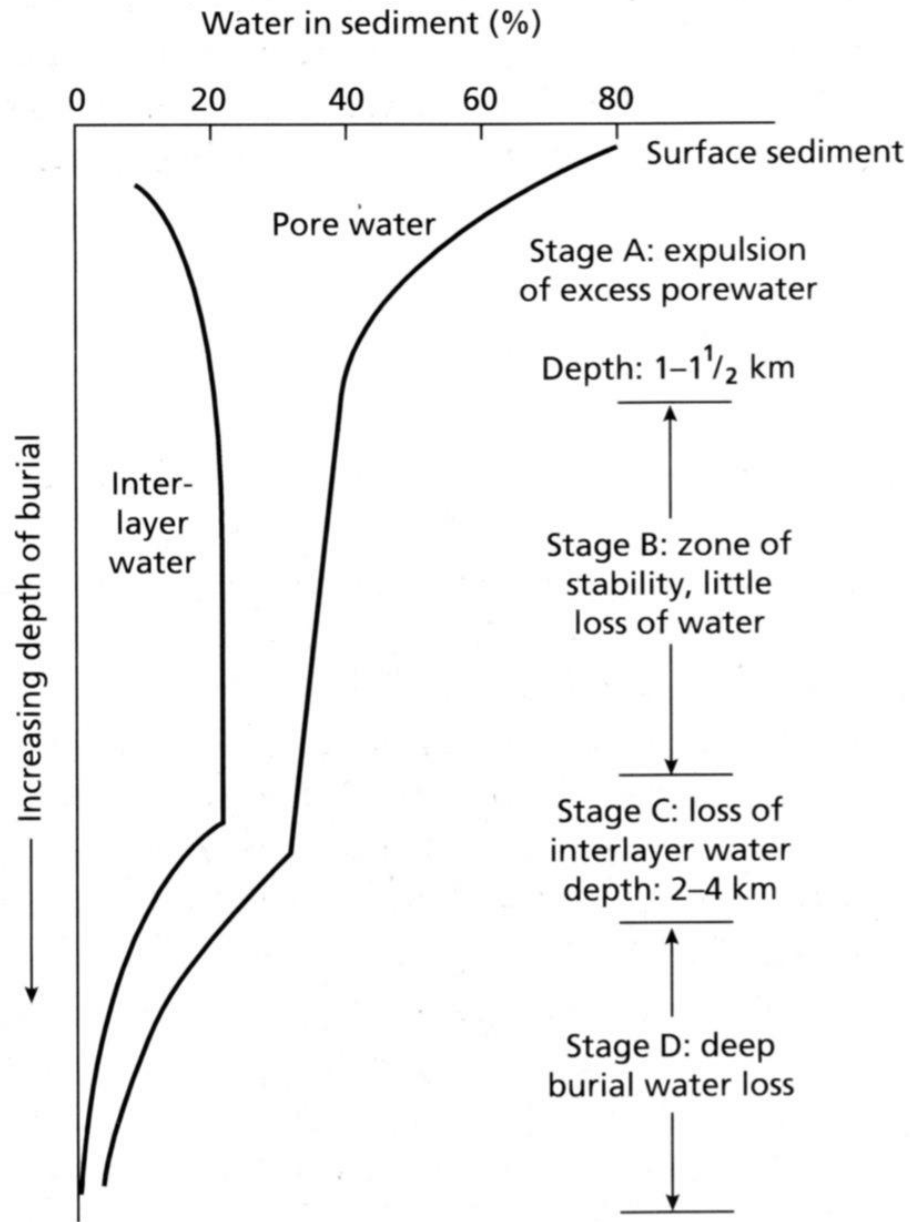


Fig. 3.8 Diagram illustrating the stages of water loss from muddy sediments with increasing depth of burial.

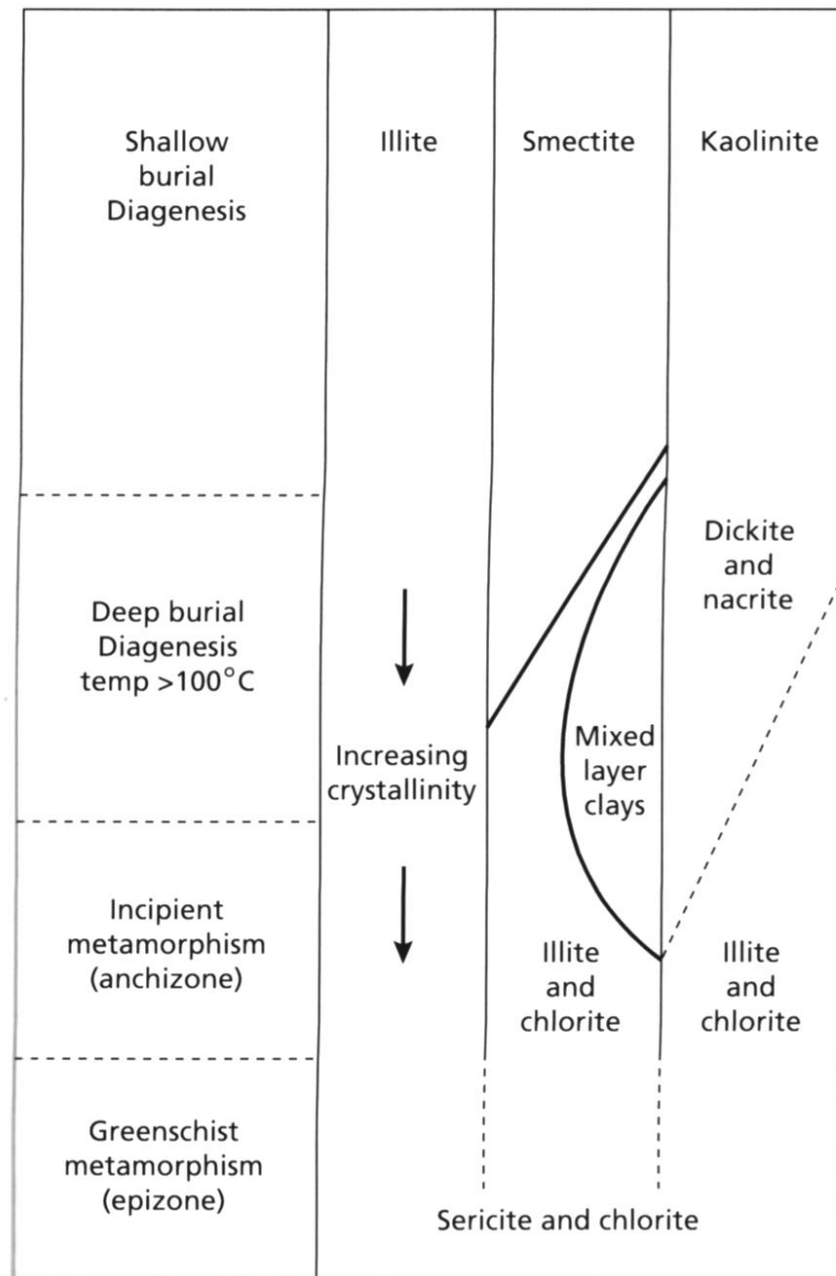
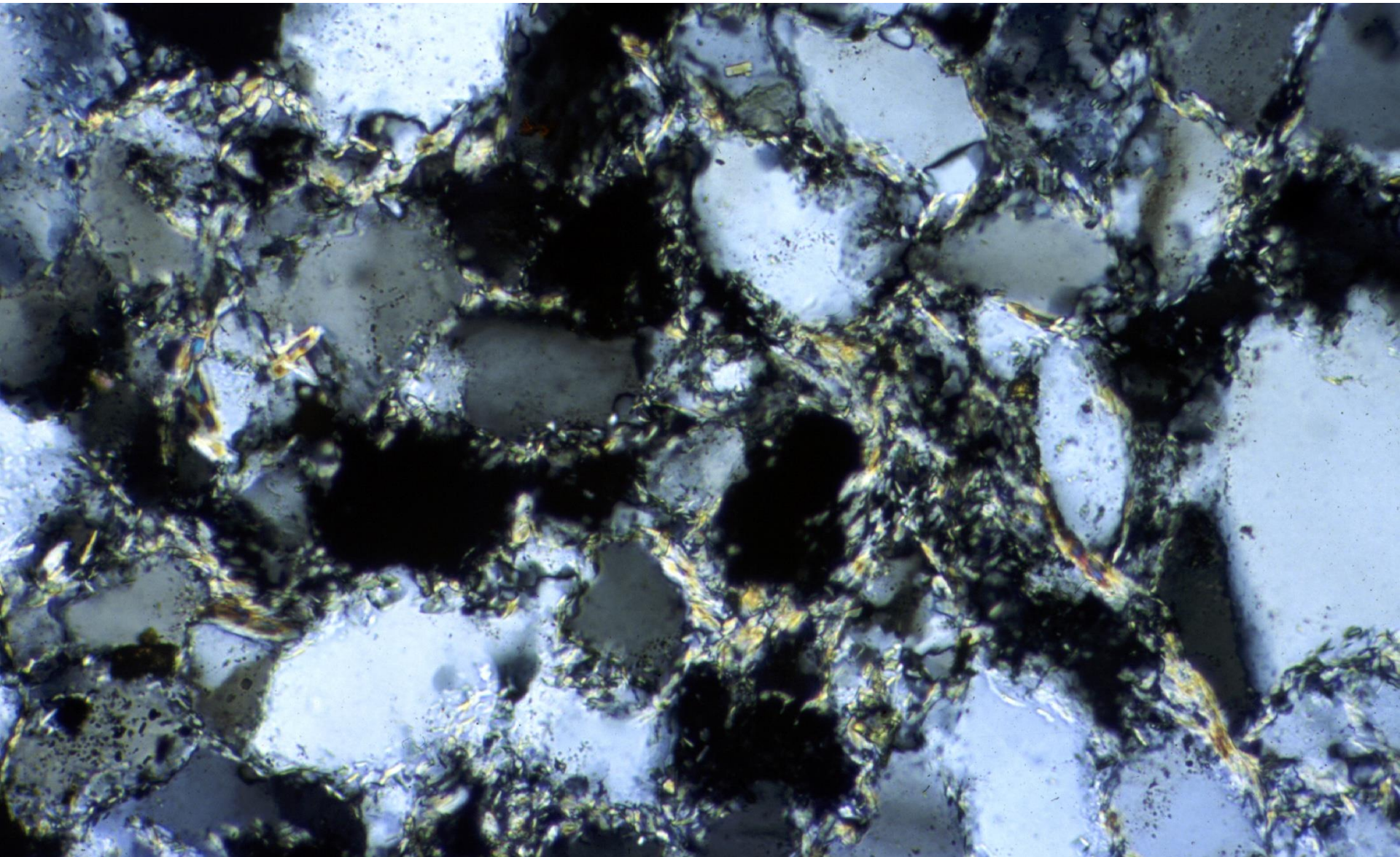


Fig. 3.9 Diagram illustrating the changes of clay minerals with increasing depth of burial and into metamorphism.

stupeň proměny a krystalinity jílových minerálů (illitu)



Čtení:

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Z.Kukal: Návod k pojmenování a klasifikaci sedimentů. ČGÚ, 1985

M.E.Tucker: Sedimentary petrology. Blackwell, 3rd ed, 2001.

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