Sedimentpetrologie:

Petrographie, Geochemie & Provenienzanalyse

(3 SWS, V/Ü)

Modul Beckenanalyse 1:
Sedimentpetrologie und Lagerstätten

Kursnummer: 600128

Hilmar von Eynatten
Abt. Sedimentologie & Umweltgeologie

WS 2014/15

Lehrangebot (Master Geowissenschaften) im Bereich Exogene Geologie / Sedimentologie / Sedimentpetrologie

(Bachelor: Praktikum Sedimentpetrographie/Sedimentologie)

WiSe

Sedimentologie und Beckenanalyse (Modul **Geodynamik 1**)

Sedimentpetrologie: Petrographie, Geochemie & Provenienzanalyse
Economical Deposits in Sedimentary Environments (Modul **Beckenanalyse 1**)

Low-Temperature Geothermometry and Geochronology in Basin Analysis
Diagenese und Verwitterung (?) (Modul **Beckenanalyse 2**)

SoSe

Geländeübung zur Sedimentgeologie (Oberkreide – Subherzyn)
Seminar zu Sedimentgeologie und Sedimentpetrologie
Angewandte Liefergebietsanalyse (Modul **Beckenanalyse 3**)

Literatur – I

General:

Füchtbauer, H. (1988): Sedimente und Sedimentgesteine.- 4. Auflage, 1141 pp, Stuttgart (Schweizerbart).

Pettijohn, F.J., Potter, P.E. & Siever, R. (1987): Sand and sandstone. 2nd edition, 553 pp, New York (Springer).

Siever, R. (1988): Sand - ein Archiv der Erdgeschichte. 254 pp, Heidelberg (Spektrum der Wissenschaft).

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Clay minerals:

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Velde, B. (1995, Ed.): Origin and mineralogy of clays.- 334 pp, Berlin (Springer).

Geochemistry:

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Literatur – II

Microscopy:

Adams, A.E., MacKenzie, W.S. & Guilford, C, (1986): Atlas der Sedimentgesteine in Dünnschliffen. 103pp, Stuttgart (Enke).

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Boenigk, W. (1983): Schwermineralanalyse.- 158 pp, Stuttgart (Enke).

Mange, M.A. & Maurer, H.F.W. (1991): Schwerminerale in Farbe.- 148 pp, Stuttgart (Enke).
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Provenance analysis:

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Johnsson, M.J. & Basu, A. (1993, Eds.): Processes controlling the composition of clastic sediments.- 342 pp, Geol. Soc. America, Special Paper, 284, Boulder/Colorado.

Weltje GJ & von Eynatten H (2004): Quantitative provenance analysis of sediments. Sedimentary Geology, vol. 171.

Literatur – III

http://www.sediment.uni-goettingen.de/skript.html

Provenance analysis:

Arribas J, Critelli S & Johnsson MJ (2007): Sedimentary provenance and petrogenesis. Geol. Soc. America, Special Paper 420, Boulder/Colorado.

von Eynatten H, Critelli S, Ingersoll RV, Weltje GJ (2012): Actualistic Models of Sediment Generation. Sedimentary Geology, vol. 280.

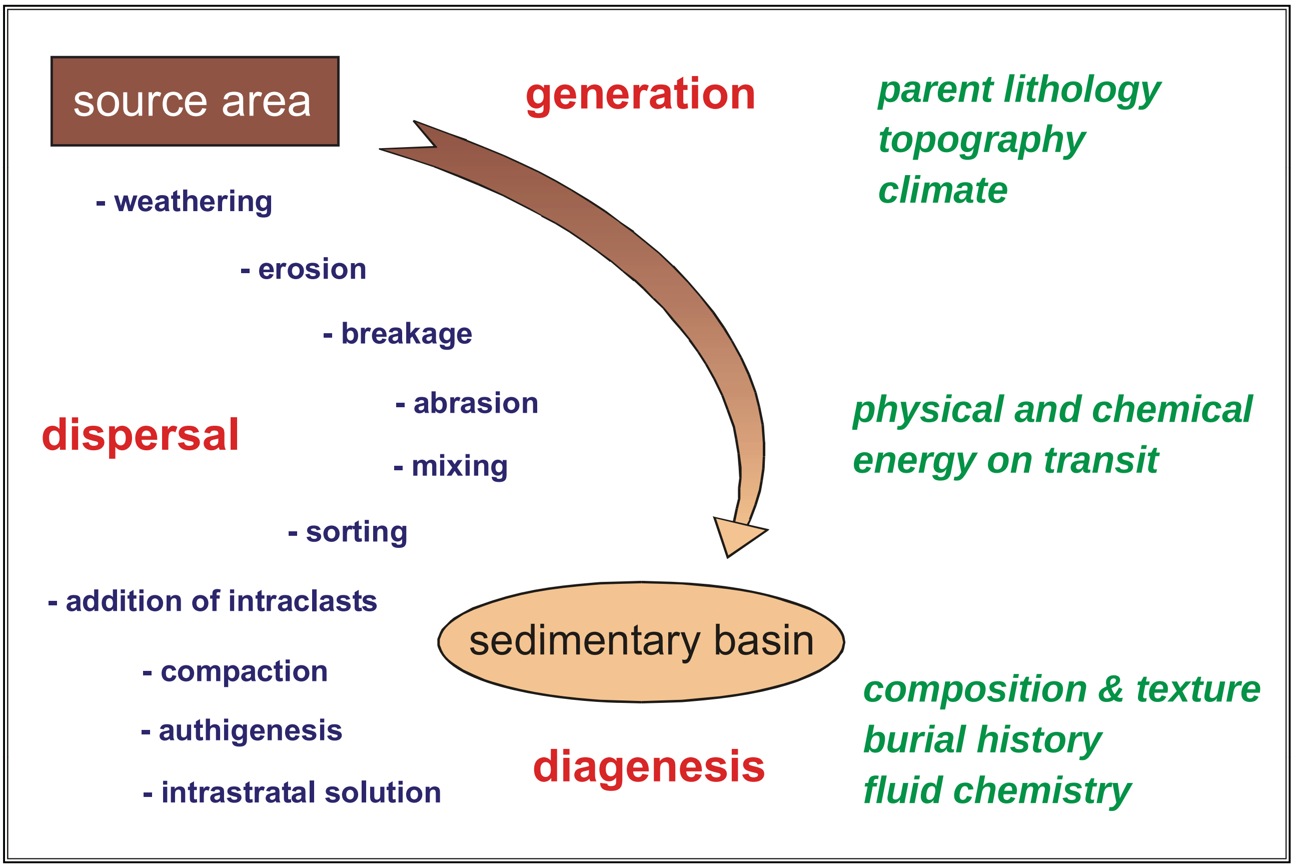
grain-size classification

Table 2.1. Standard grain-size scales for carbonate and clastic sediments.[a]

Limiting particle diameter: m	mm	ϕ units[b]	Micrometers (μm)	Clastic rocks			Carbonate rocks: Transported constituents	Carbonate rocks: Authigenic constituents
	2048	−11		V. large	Boulders	Gravel	V. coarse calcirudite	Extremely coarsely crystalline
1	1024	−10		Large				
	512	− 9		Medium				
	256	− 8		Small				
10^{-1}	128	− 7		Large	Cobbles			
	64	− 6		Small				
	32	− 5		V. coarse	Pebbles		Coarse calcirudite	
	16	− 4		Coarse				
10^{-2}	8	− 3		Medium			Medium calcirudite	
	4	− 2		Fine				
	2	− 1		V. fine			Fine calcirudite	Very coarsely crystalline
10^{-3}	1	0		V. coarse	Sand			
	1/2	+ 1	500	Coarse			Coarse calcarenite	Coarsely crystalline
	1/4	+ 2	250	Medium			Medium calcarenite	
10^{-4}	1/8	+ 3	125	Fine			Fine calcarenite	Medium crystalline
	1/16	+ 4	62	V. fine			V. fine calcarenite	
	1/32	+ 5	31	V. coarse	Silt		Coarse calcarenite	Finely crystalline
	1/64	+ 6	16	Coarse			Medium calcilutite	
10^{-5}	1/128	+ 7	8	Medium			Fine calcilutite	Very finely crystalline
	1/256	+ 8	4	Fine			V. fine calcilutite	
	1/512	+ 9	2	V. fine				Aphanocrystalline
10^{-6}					Clay/mud			

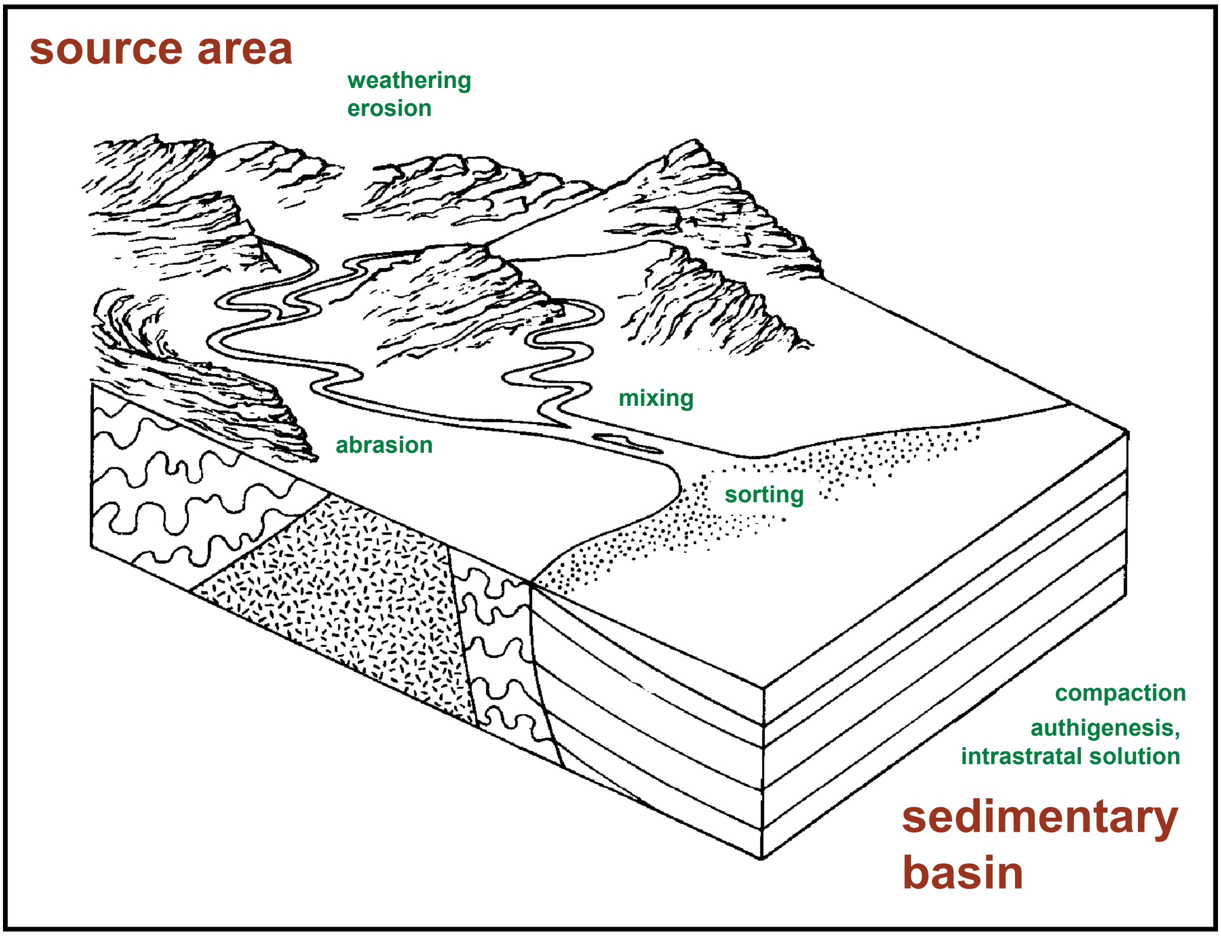
[a] After Friedman and Sanders, 1978; Folk, 1968. Reproduced, with permission, from G.M. Friedman and J.E. Sanders, Principles of Sedimentology, © 1978, John Wiley and Sons, Inc., New York.
[b] Phi (ϕ) scale is given by $-\log_2$ of particle diameter.

Miall 1990



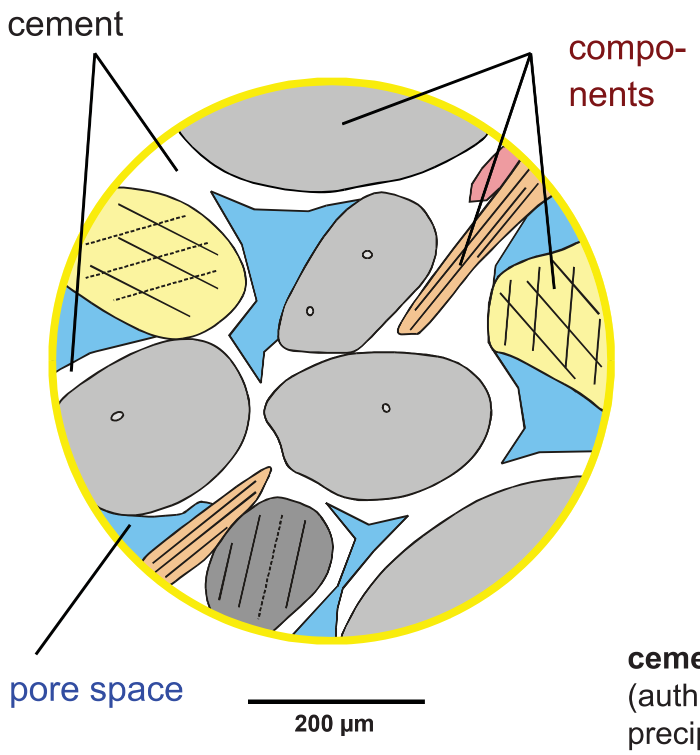
Weltje & von Eynatten 2004, Sed Geol 171

what is provenance analysis ?



modified after Morton & Hallsworth 1994

Arenites / Sandstones



components: (clasts)
quartz,
feldspar,
rock fragments (lithoclasts),
mica,
bioclasts/-morphs,
heavy minerals,
etc...

pore space: (pore fill)
water,
petroleum (crude oil)
gases (CO_2, CH_4, H_2S, H_2O, N_2, O_2 ...)

cements: (authigenic precipitates)
quartz, hematite
calcite, dolomite, siderite, ankerite,
anhydrite, halite
chlorite, kaolinite, illite, smectite, ...

Themen:

(A) components

(B) texture - structure

(C) classification

(D) provenance analysis

(E) geochemical indicators

(F) Heavy mineral analysis

(G) case studies

HvE - Sedimentpetrologie

(A) components

1. quartz and other SiO_2 - polymorphs

quartz is the most common mineral in arenites → ∅ **65%**

comp.:	
shale	~30%
pelagic ooze	~10%

Why ?

frequency of quartz in crystalline rocks → **~ 20%**

Low - Temp - Quarz („Niedrig-Quarz", T < 573°C, trigonal, ρ = 2,65 g/cm^3)

→ this is the only crystalline polymorph of SiO_2, which is stable under „sedimentary conditions"

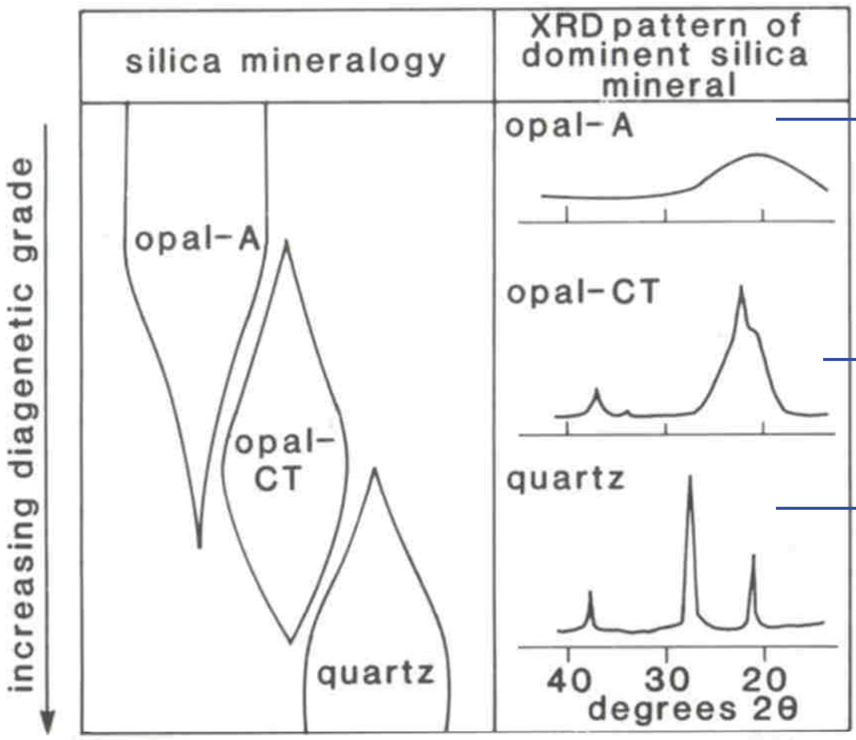


Fig. 9.6 Schematic changes in silica mineralogy with increasing diagenesis, and X-ray diffraction patterns for opal-A, opal-CT and quartz showing the increasing crystallinity. After Pisciotto (1981).

→ Amorphous silica (SiO_2 x nH_2O); variable water content: 11-14 wt.-% (radiolarian ooze) 2-10% (diatom ooze)

→ „metastable", 0.5-7% H_2O

→ chalcedony or mikro-/crypto-crystalline quartz ("chert"): 0-2% H_2O;

„normal"-quartz, pure SiO_2, ± 0% H_2O

Tucker 1991

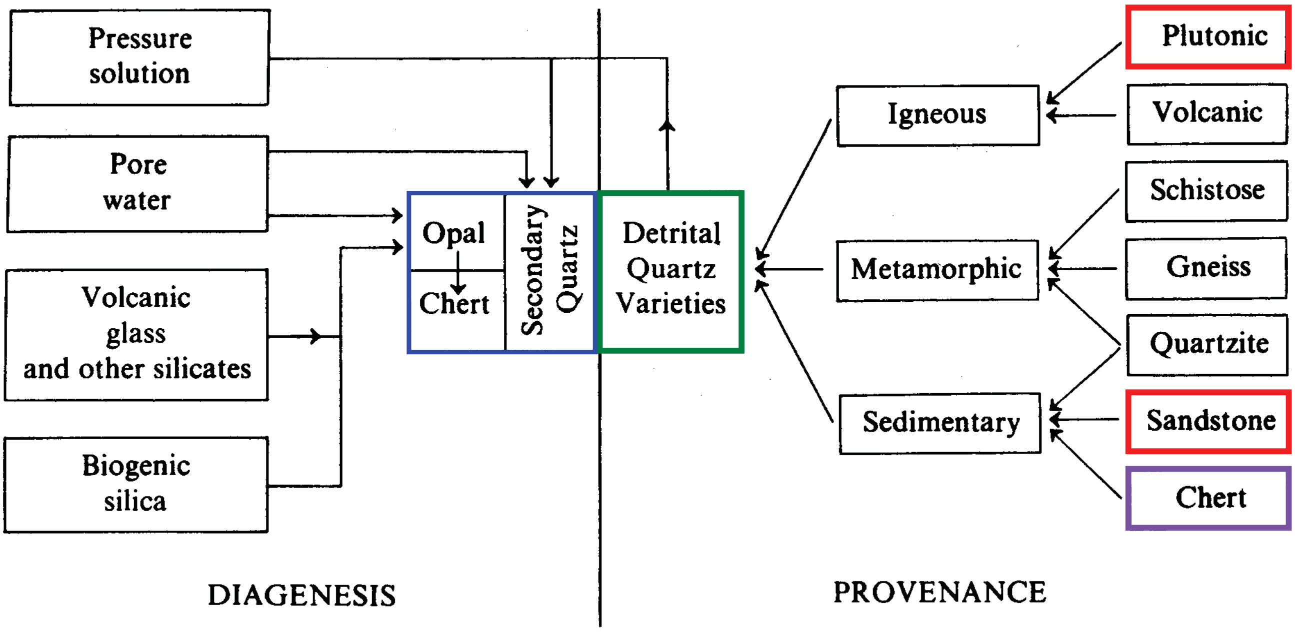


FIGURE 2-4. The origin of silica minerals in sandstones.

Pettijohn et al. 1987 S.32

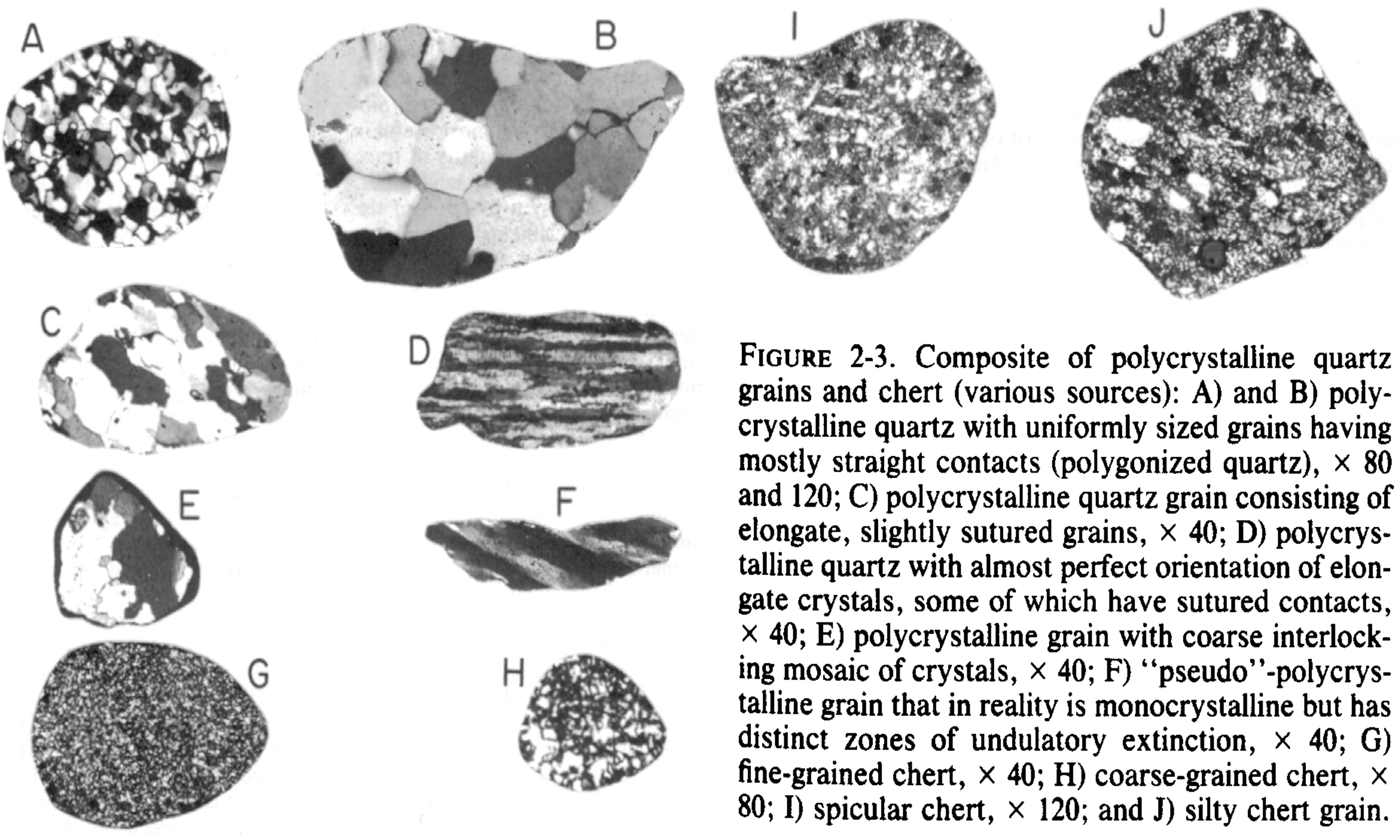
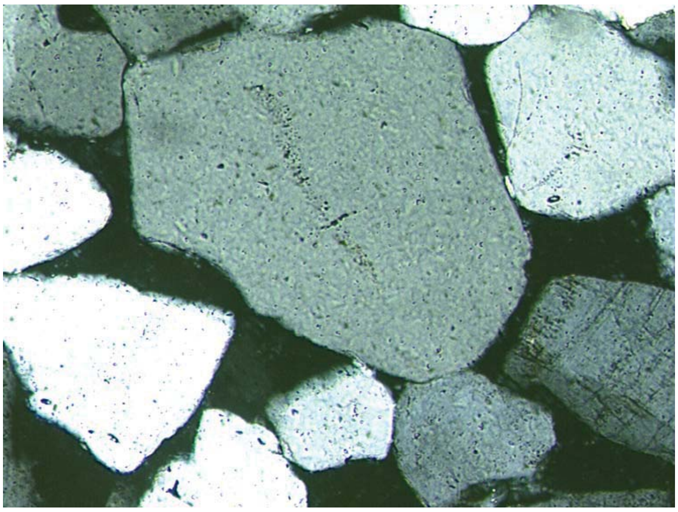
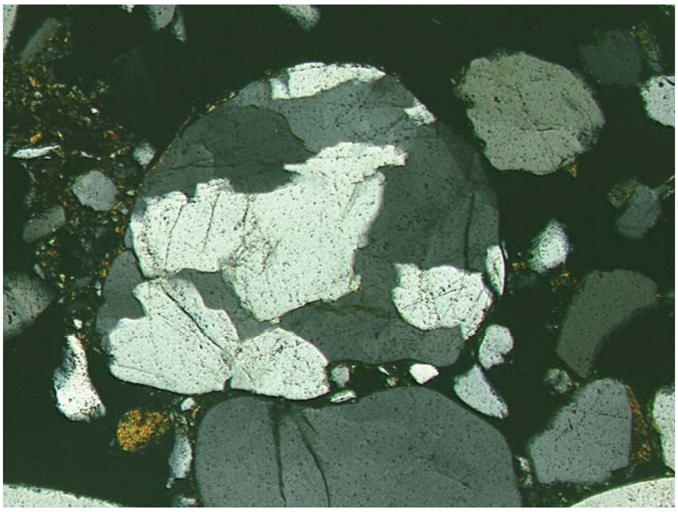


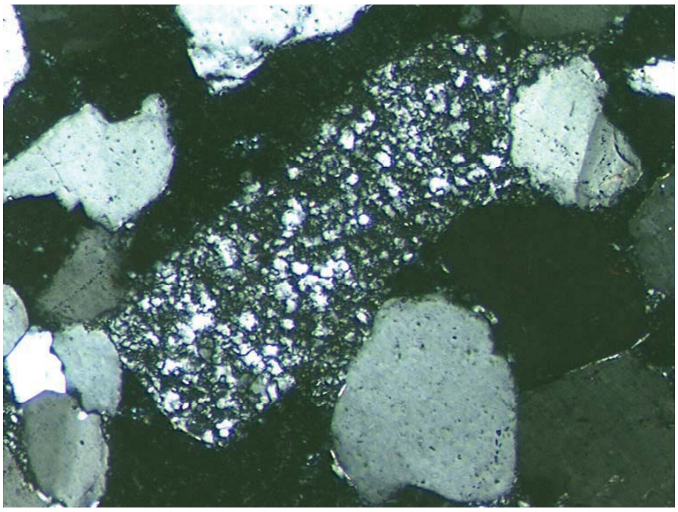
FIGURE 2-3. Composite of polycrystalline quartz grains and chert (various sources): A) and B) polycrystalline quartz with uniformly sized grains having mostly straight contacts (polygonized quartz), × 80 and 120; C) polycrystalline quartz grain consisting of elongate, slightly sutured grains, × 40; D) polycrystalline quartz with almost perfect orientation of elongate crystals, some of which have sutured contacts, × 40; E) polycrystalline grain with coarse interlocking mosaic of crystals, × 40; F) "pseudo"-polycrystalline grain that in reality is monocrystalline but has distinct zones of undulatory extinction, × 40; G) fine-grained chert, × 40; H) coarse-grained chert, × 80; I) spicular chert, × 120; and J) silty chert grain.

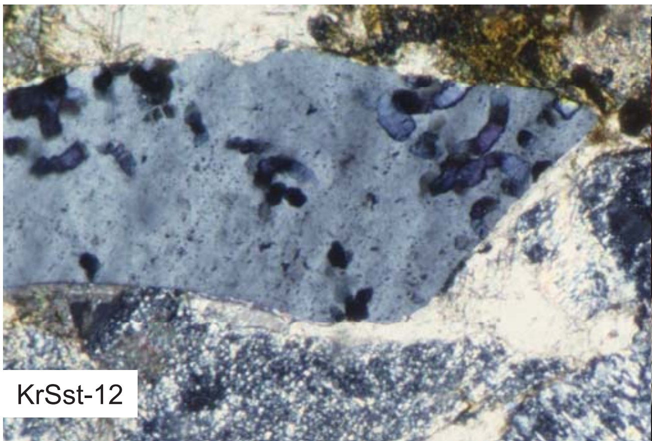
Pettijohn et al. 1987 S.31

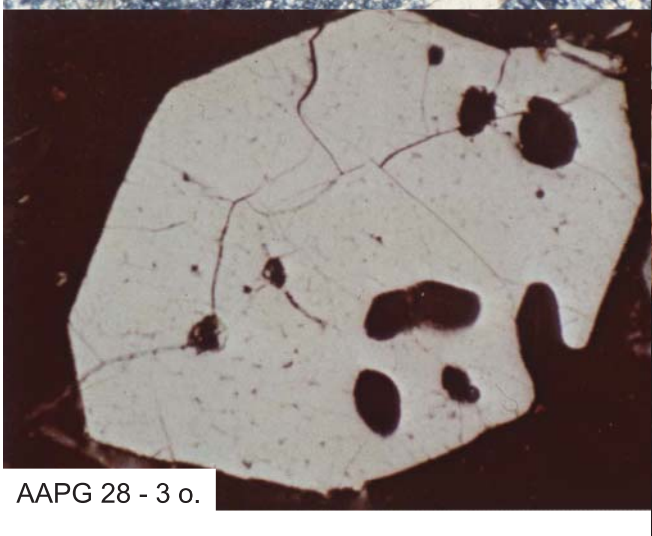


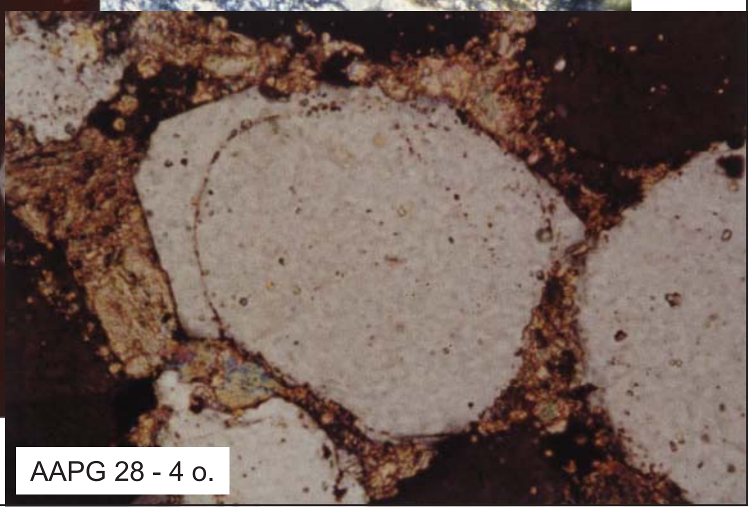


A. Meyer (Diplomarbeit 2003)









HvE - Sedimentpetrologie

2. Feldspar

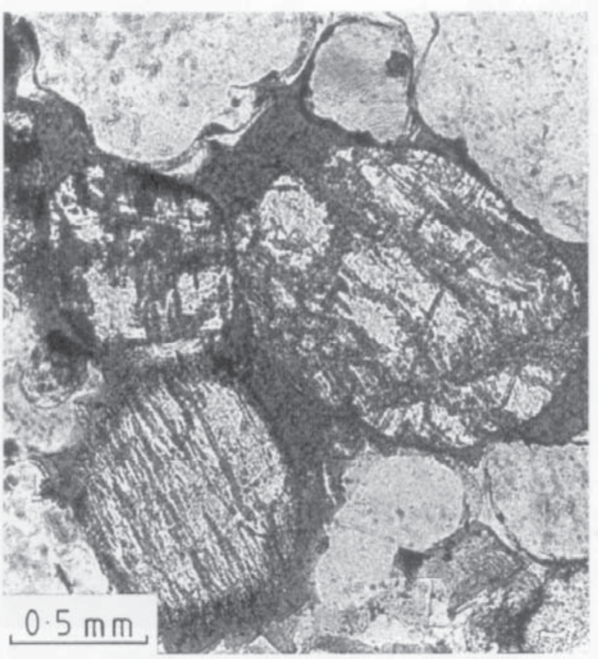


Fig. 2.54 Three feldspar grains showing the effects of dissolution along cleavage and fracture planes, and around their margins. The upper two are orthoclase and the lower left one is plagioclase (crossed polars required to confirm). Other grains are all quartz, some with syntaxial overgrowths. Slide impregnated with blue resin (here grey) to show porosity, which is reduced primary intergranular and dissolutional porosity. Plane polarized light. Permian aeolian sandstone. NE England.

Tucker 1991 S.44

TABLE 2-2. Feldspar content of North American sands and sandstones.

Age	Number of formations	Percent feldspar
Pre-Devonian	35	5.1
Devonian–Permian	29	5.8
Mesozoic	12	25.0
Tertiary	22	21.0
Pleistocene–Recent		15.3
Unweighted mean		14.4

Pettijohn et al. 1987 S.36

TABLE 2-3. Feldspar content of sandstones of Russian platform (Ronov *et al.*, 1963).

Age	No. of samples	Feldspar
Precambrian	65	30.5
Cambrian	18	16.6
Silurian	14	9.6
Devonian	177	8.9
Carboniferous	95	4.8
Triassic	5	61.6
Jurassic	23	42.8
Cretaceous	20	15.0
Tertiary	10	31.1
Quaternary	8	22.6
	Average	15.3

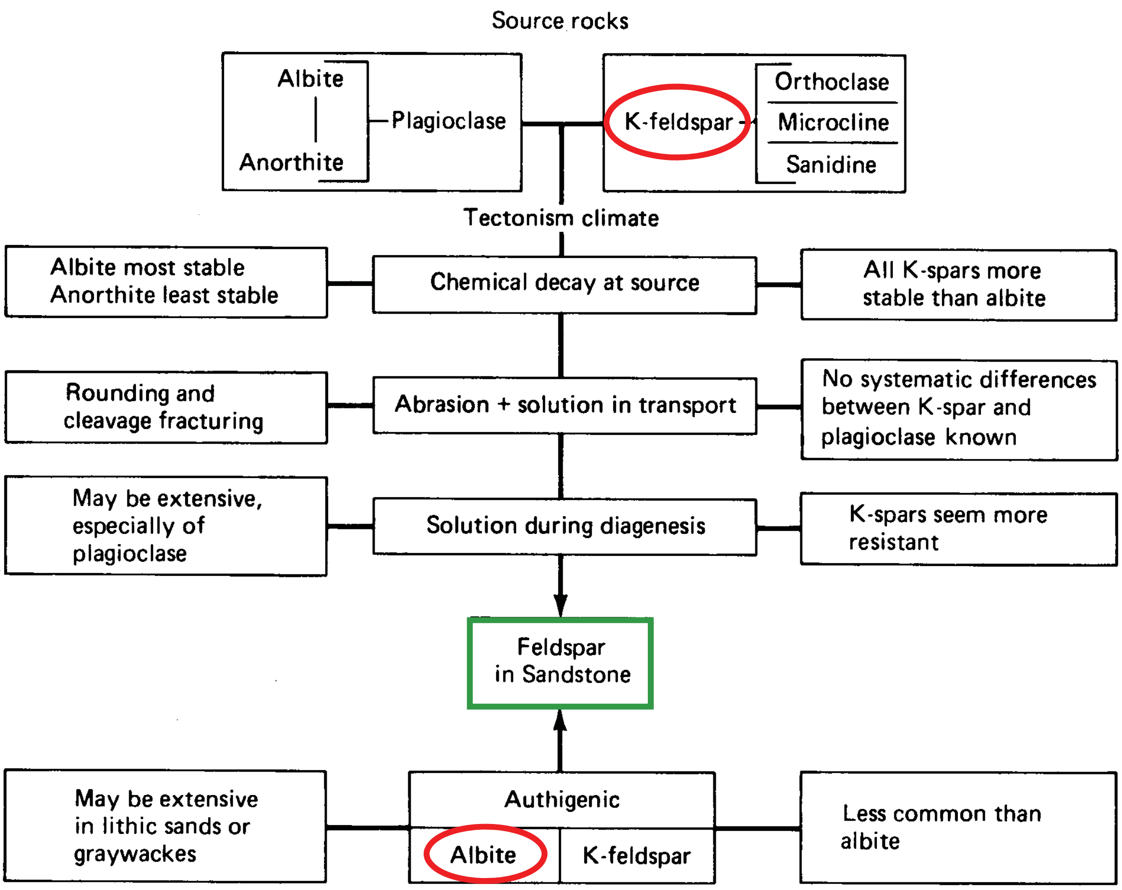
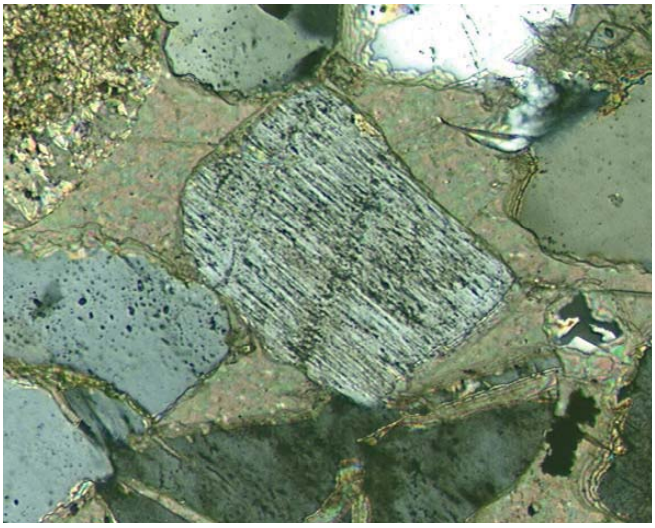
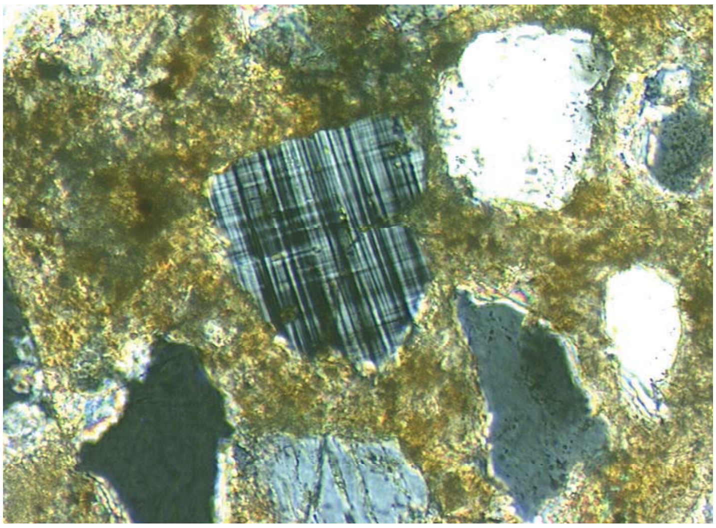


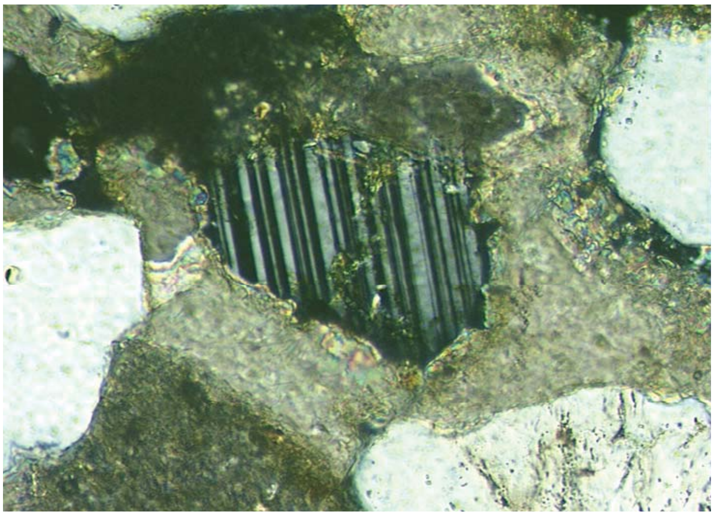
FIGURE 2-6. The origin of feldspars in sandstones.

Pettijohn et al. 1987 S.37

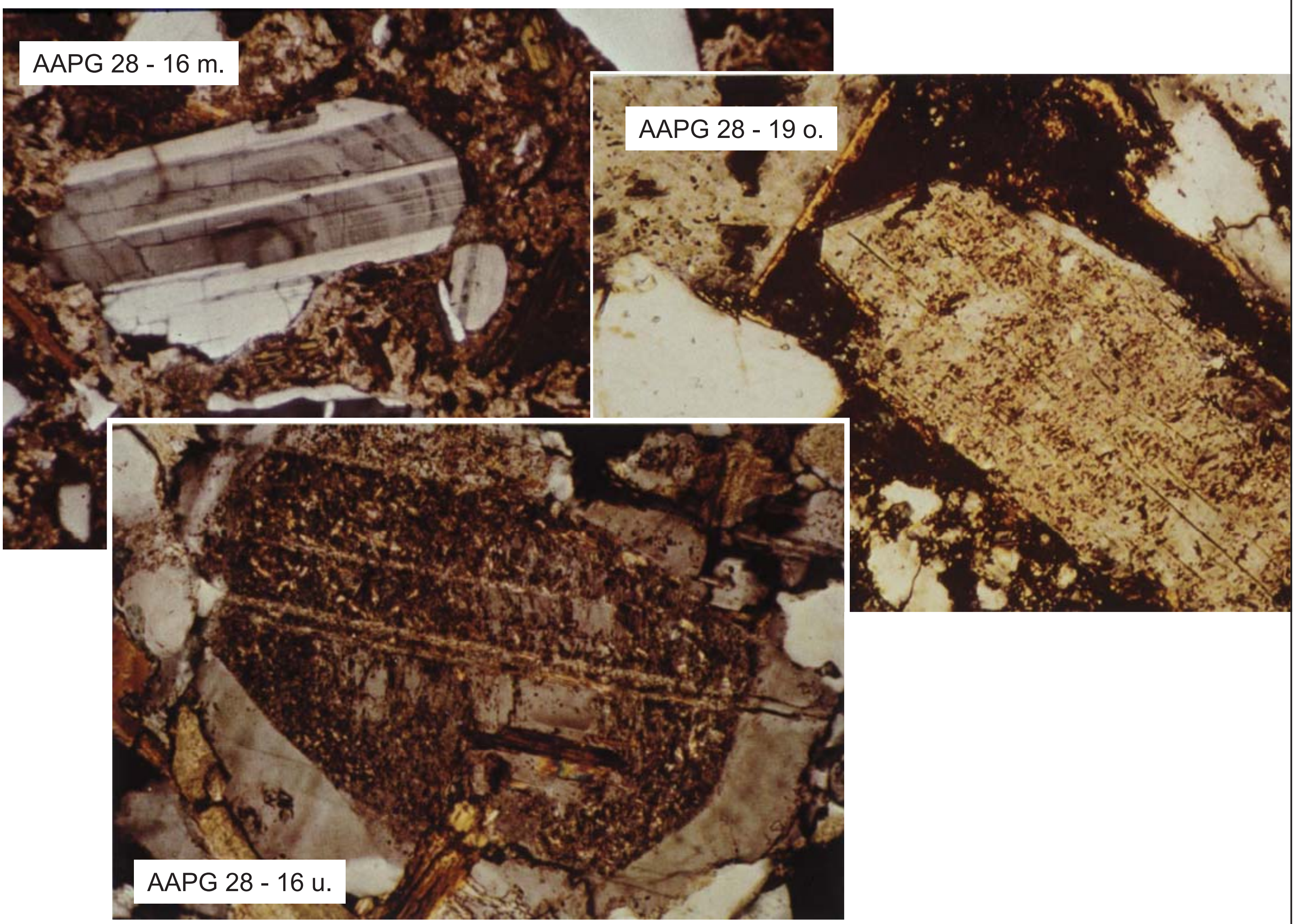




A. Meyer (Diplomarbeit 2003)



HvE - Sedimentpetrologie



HvE - Sedimentpetrologie

3. Rock fragments (lithoclasts)

- volcanic (fragments of basalts, andesites, rhyolites, pyroclastics, volcanic glass, etc..., $\mathbf{L_v}$)
- sedimentary ($\mathbf{L_s}$), metasedimentary ($\mathbf{L_{sm}}$) and metamorphic ($\mathbf{L_m}$) lithoclasts (e.g. mudrocks, shales, slates, phyllites, quartzites, mica schists, gneisses, etc...)
- cherts (radiolarites, lydites) and other polycrystalline quartz types ($\mathbf{Q_c}$ / $\mathbf{Q_p}$)
- carbonate lithoclasts ($\mathbf{L_c}$ / **C**)

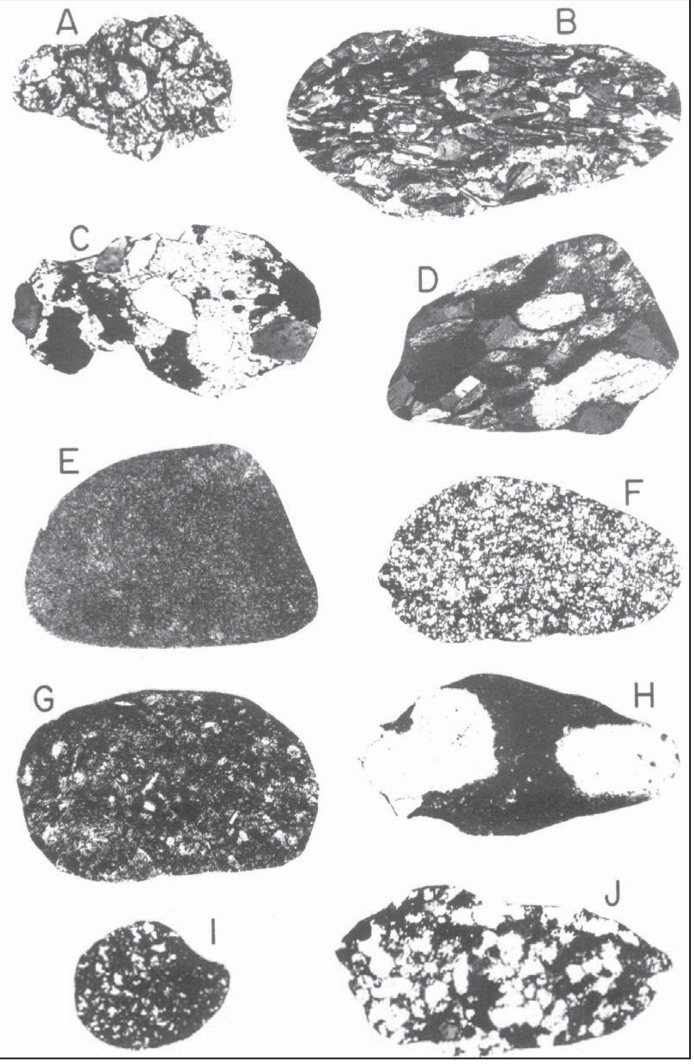


FIGURE 2-9. Rock fragments from modern sands of the Ohio River Basin, U.S.A., × 80: A) detrital carbonate; B) muscovite schist; C) sandy carbonate; D) hornblende schist; E) micritic limestone; F) microcrystalline carbonate; G) silty shale; H) sandstone cemented by chert; I) chert; and J) coarse siltstone. Photographs courtesy of James F. Friberg.

Pettijohn et al. 1987 S.44

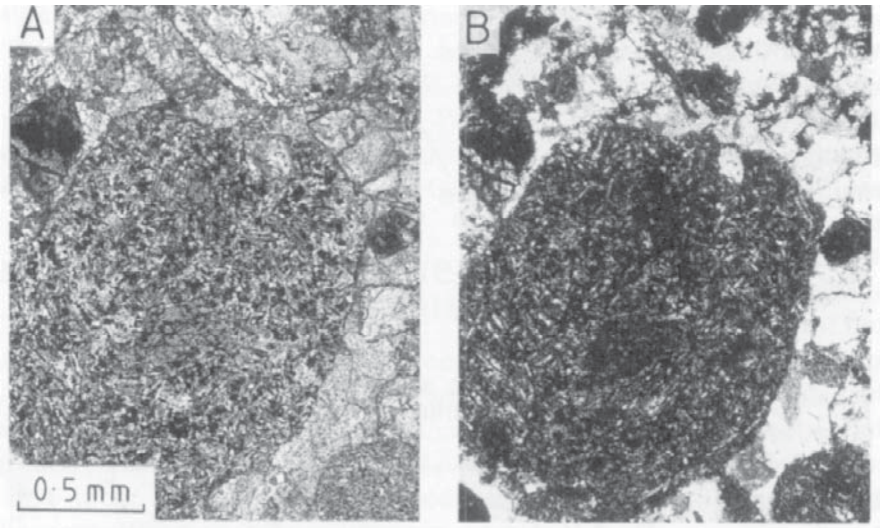


Fig. 2.48 Lithic grains of volcanic origin. The larger grain consists of minute feldspar laths in a glassy grundmass, and the smaller grain (at the top) is a feldspar crystal partly replaced by calcite. The cement is also calcite and there are smaller fragments of volcanic material in that too. A. planc-polarized light. B. Crossed polars. Triassic shallow-marine sandstone. The Dolomites, Italy.

Tucker 1991 S.40

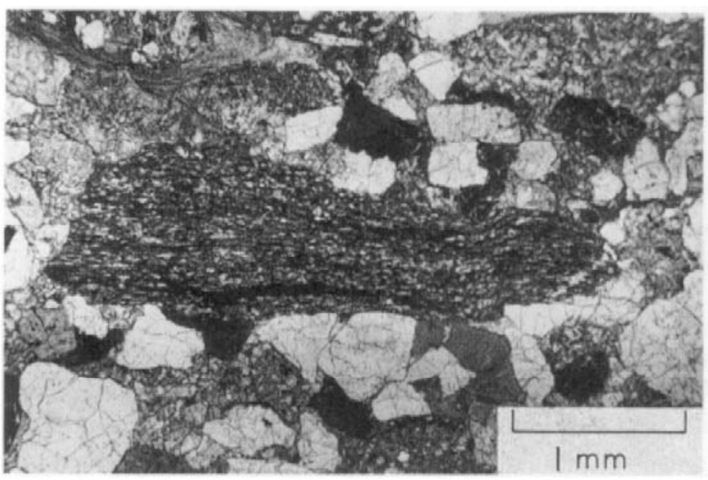


Fig. 2.47 Fragment of laminated shale, also other lithic and quartz grains in greywacke. Plane-polarized light. Silurian turbidite (deep-marine). Southern Uplands, Scotland.

Tucker 1991 S.39

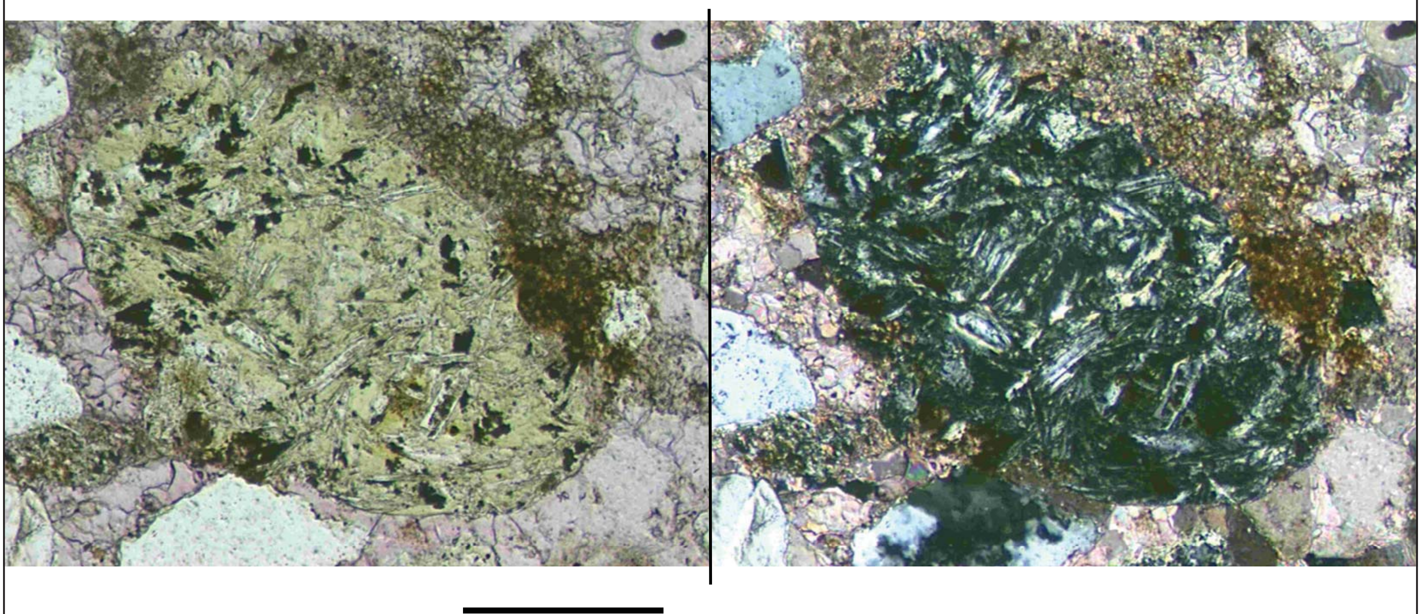
includes (detrital) chert grains!

TABLE 2-4. Rock fragment content of North American Recent and Pleistocene sands.

Type	Locality	No. of samples	Range	Average	Reference
River	Mississippi River	62	9 to 19	13	Russell (1937)
River	Ohio River	1	—	11	Hunter (1967)[a]
River	Mississippi River (below junction of Missouri)	2	22 to 27	24	Hunter (1967)[a]
River	Columbia River	11	—	31	Whetten (1966)[b]
Rivers, small	Mexican streams	7	45 to 69	57	Webb and Potter (1969)
River, small	Jacalitos Creek, California	1	—	40	Gilbert *in* Williams *et al.* (1954, p. 285)
River	Rio Grande, Texas	1	—	40	Nanz (1954)[c]
Average river		85		20	
Beach	Lake Michigan	2	—	17	Hunter (1967)[a]
Beach	Texas	2	—	15	Nanz (1954)[c]

[a] Data from 1.25–2.75ϕ range only.
[b] Includes some coarse silt grades also.
[c] Estimated from published plot.

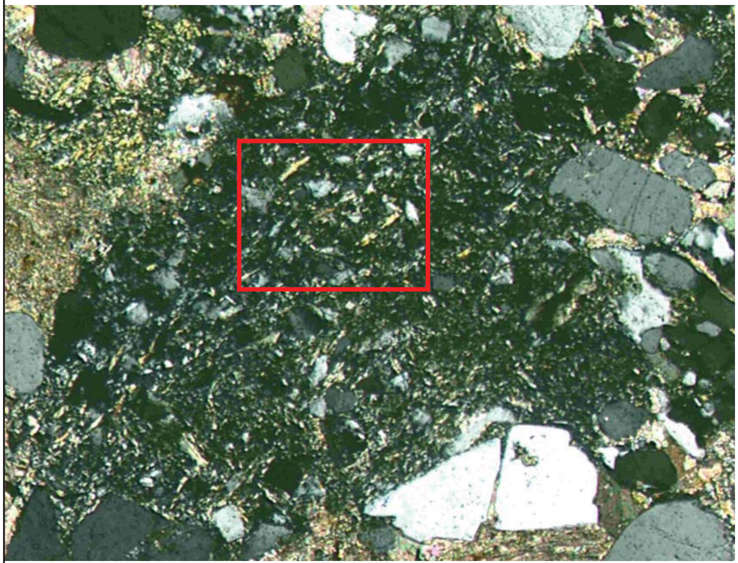
Pettijohn et al. 1987 S.45

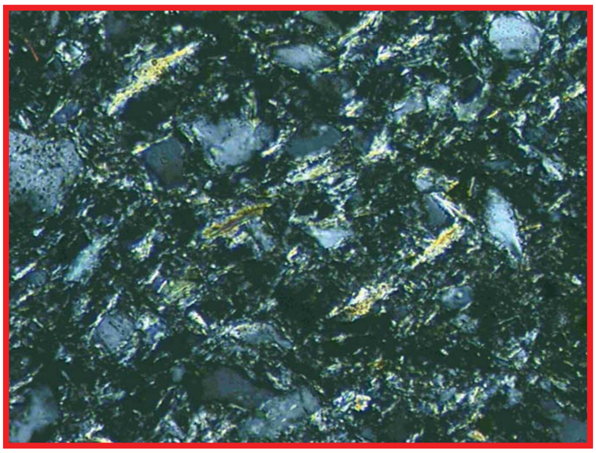


200 µm

A. Meyer (Diplomarbeit 2003)

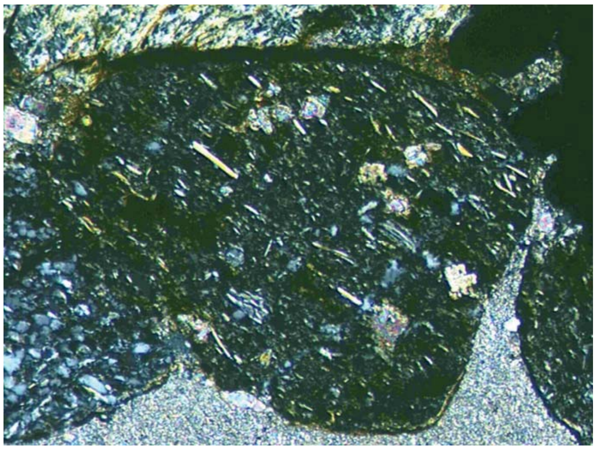
→ basic volcanic clast,
chloritized matrix (illite as well?),
many opaque phases (ilm, mag, ...)
plagioclase phenocrysts showing no
preferred orientation



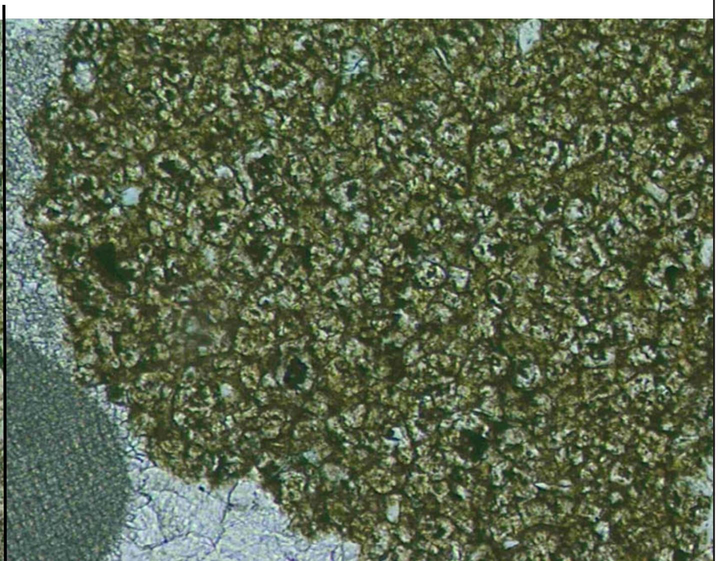


300 µm

A. Meyer (Diplomarbeit 2003)



→ sedimentary to *low-grade* metamorphic
(metasedimentary) lithoclasts;
Late Paleozoic, Harz Mountains



A. Meyer (Diplomarbeit 2003) 300 µm

A. Meyer (Diplomarbeit 2003) 100 µm

→ more types of carbonate clasts
left: pure micrite (mudstone)
right: dolomite clast, see contrast to calcite-cement (sparite),
lower left: red algae

4. Further components

- phyllosilicates
  chlorite, mica, clay minerals

detrital or authigenic ?

- bioclasts / biomorphs
  shells, echinoderms, foraminifera, algae, spiculae, etc.; and fragments thereof

- coated grains
  ooids, oncoids, peloids (fecal pellets)

- intraclasts (resedimented clasts from the same area/time))

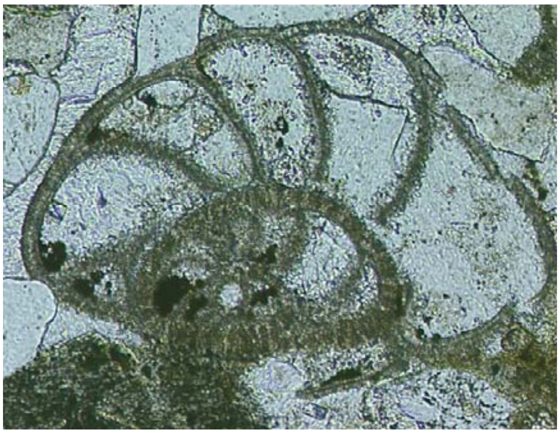
- heavy minerals

- other
  phosphates (bone fragments), glaukonite, chamosite, etc.

detrital or authigenic ?

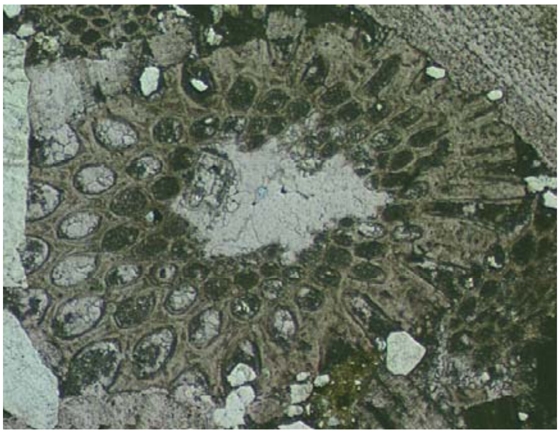
foraminifer (Neoflabelina)

300 µm



foraminifer (Lenticulata)

300 µm



bryozoe („Moostierchen“)

1000 µm

red algae

100 µm

general scheme of heavy mineral stability
(from Mange & Maurer 1991 S.8)

sehr instabil
- Olivin

instabil
- Hornblende
- Aktinolith
- Augit
- Diopsid
- Hypersthen
- Andalusit

mäßig stabil
- Epidot
- Disthen
- Granat (Fe-reich)
- Sillimanit
- Titanit
- Zoisit

stabil
- Apatit
- Granat (Fe-arm)
- Staurolith
- Monazit

extrem stabil
- Rutil
- Zirkon
- Turmalin
- Anatas

heavy minerals

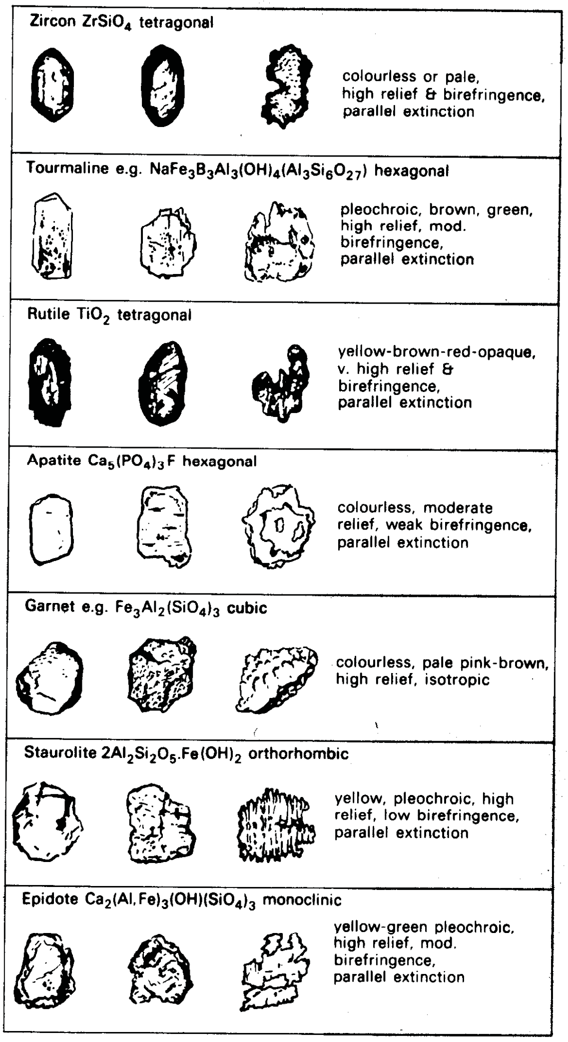
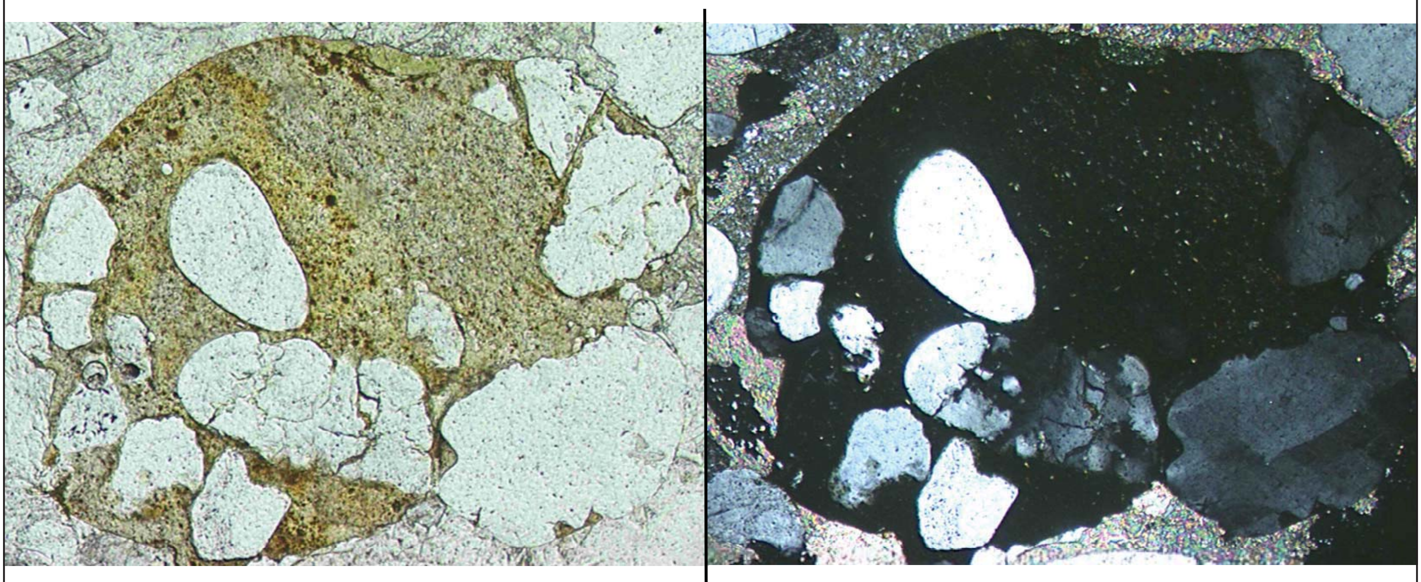


Fig. 2.55 Sketches of the seven most common heavy minerals (with the degree of weathering and or dissolution increasing to the right) together with their optical properties. After Füchtbauer (1974).

Tucker 1991 S.45



300 µm

A. Meyer (Diplomarbeit 2003)

→ phosphorite particle with detrital quartz grains