Microscopy as a tool for understanding the evolution of Portland cement technology in the second half of the 19th century

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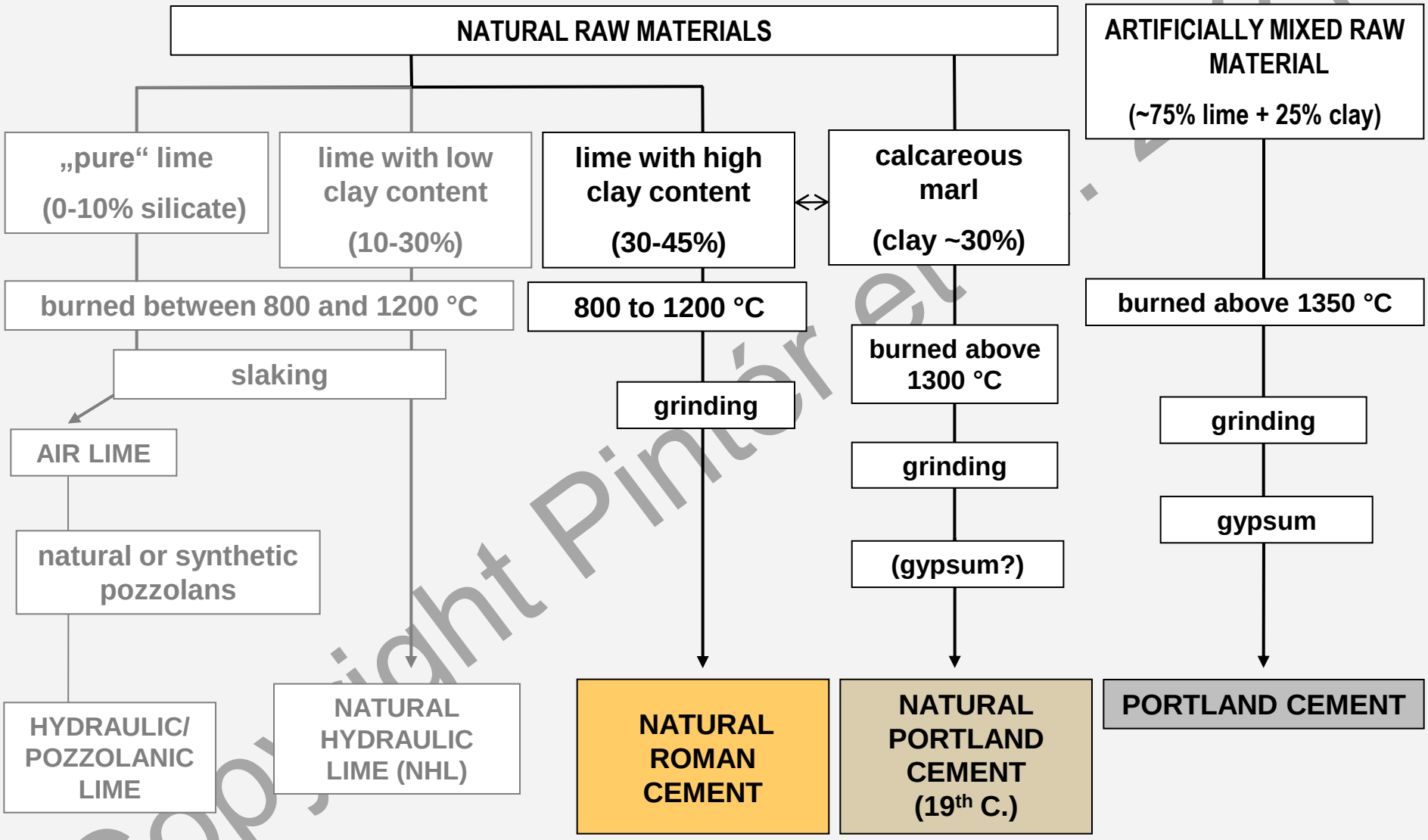
webinar CEMRESTORE, 14th April 2021

The classification of calcareous hydraulic binders



A brief history of Portland cement in the 19th century

- from the middle of the 18th century → deliberate experiments to produce hydraulic binders (Smeaton, Parker, Vicat, etc.)

- in the 19th century several patents for hydraulic cements → in 1824 Joseph Aspdin´s patent no. 5022 “Portland cement”; named after the Portland stone (precious building stone) → Aspdin´s cement ~ hydraulic lime ⟶ lime rich raw material calcined at low temperature (precursor to modern PC)

- William Aspdin / IC Johnson → clinkered (over burnt) material increases the strength of the cement (mid-1840s) → vitrified material, formation of C_3S

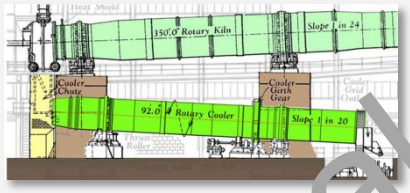
- 1880-90s first attempts to construct a rotary kiln → 1898 Hurry & Seaman first fully operating rotary kiln (USA), 1900 (UK)

- end of 1880s-1900 → use of gypsum (anhydrite) as a setting retarder

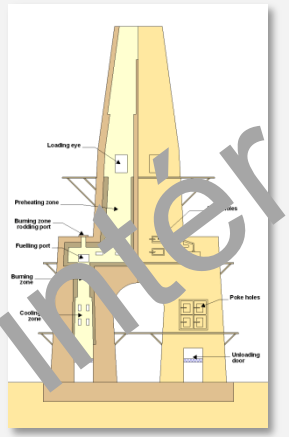
- invention of ball mills → increase of cement fineness

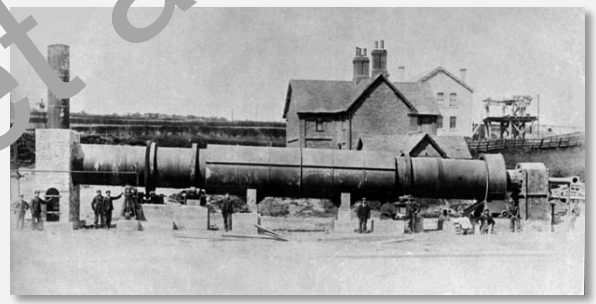
Main technological developments of the PC production between 1840 and 1910

calcium sulphate as a retarder(?)



clinker coolers

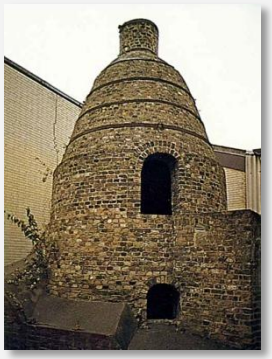




rotary kilns

continuous shaft kilns

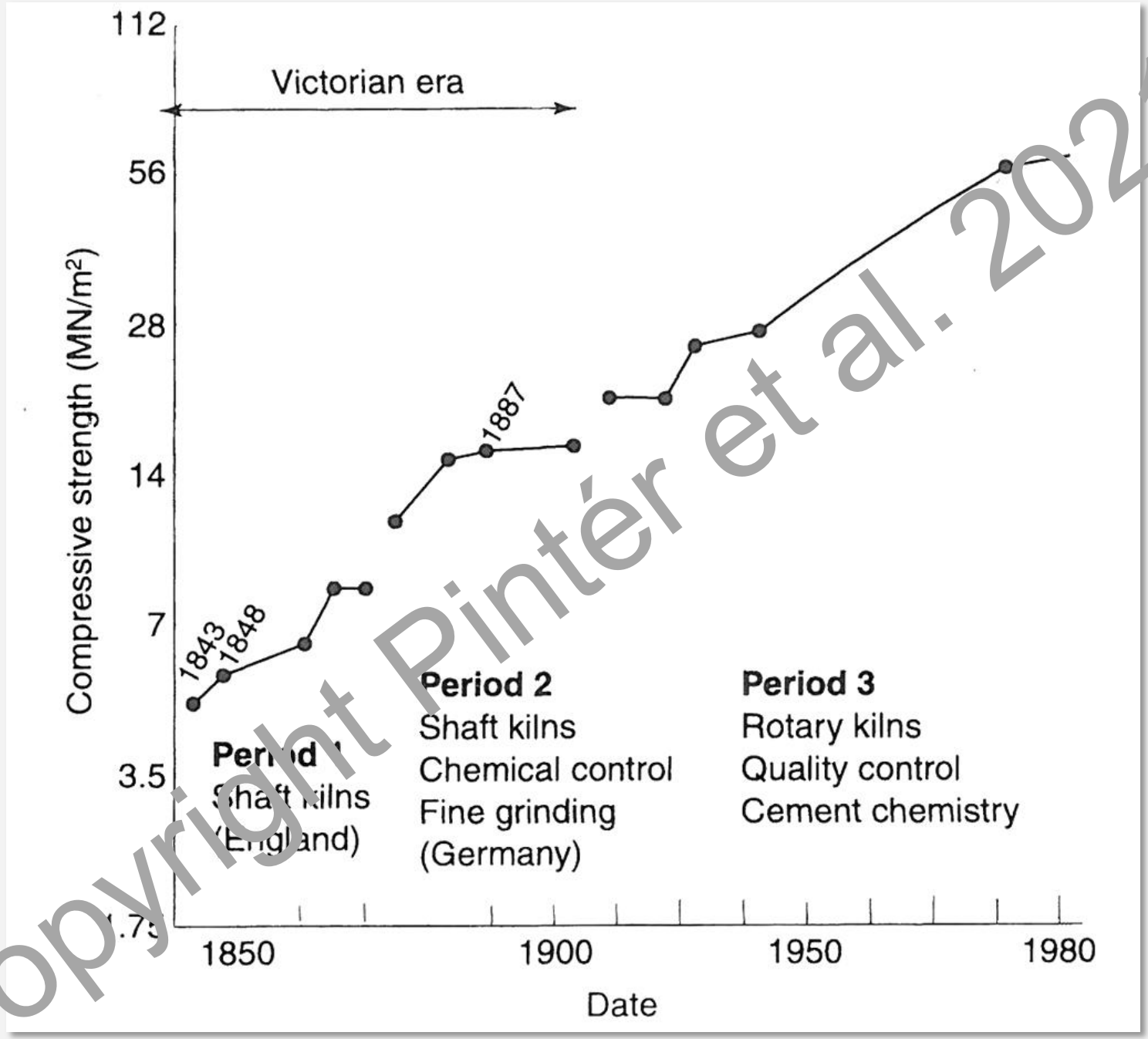
Hoffmann (ring) kilns (predominantly in Germany)



simple bottle and shaft kilns

Images: cementkilns.co.uk

1840s 1850 1860 1870 1880 1890 1900 1910



Lea´s chemistry of cement and concrete


Ulm,1879


Weißenbach a.d. T.,1893


Vienna,1903-07

Freiburg,
1860-70s

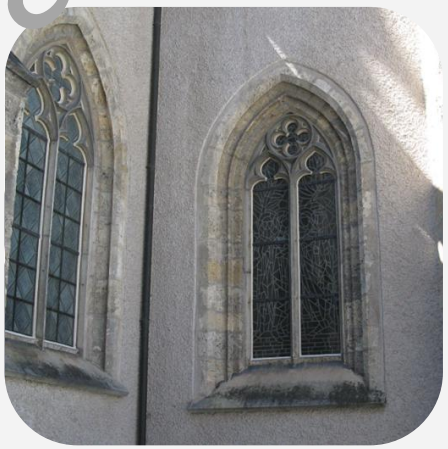

Bregenz, 1893

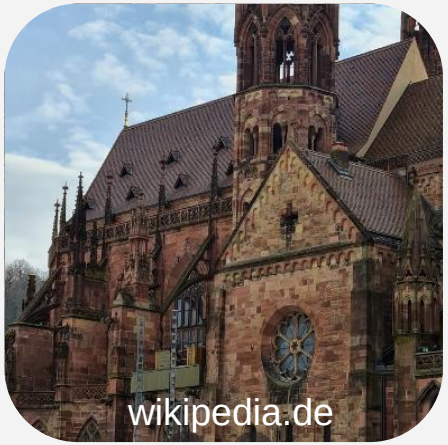

Salzburg, 1867


Admont, 1869-71

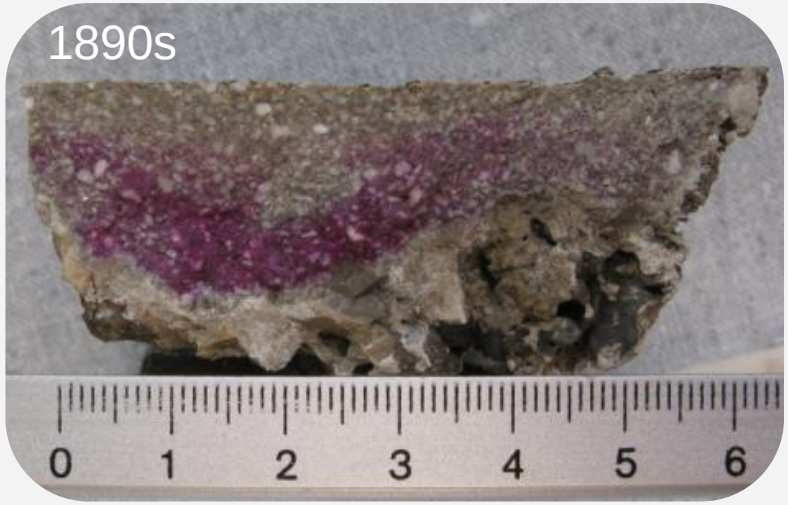

Budapest,1906-07

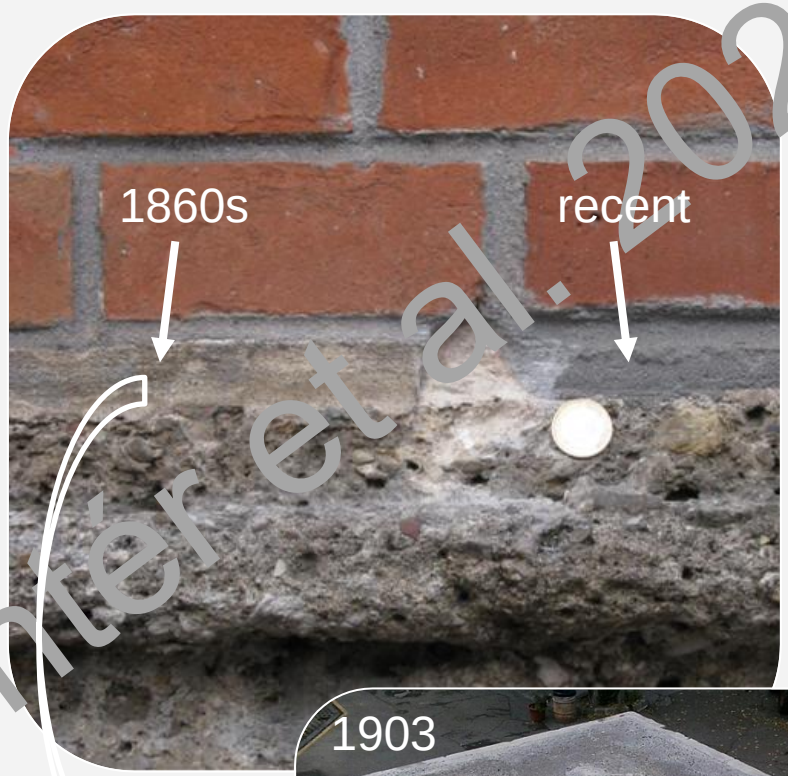

Aventicum, 1890s





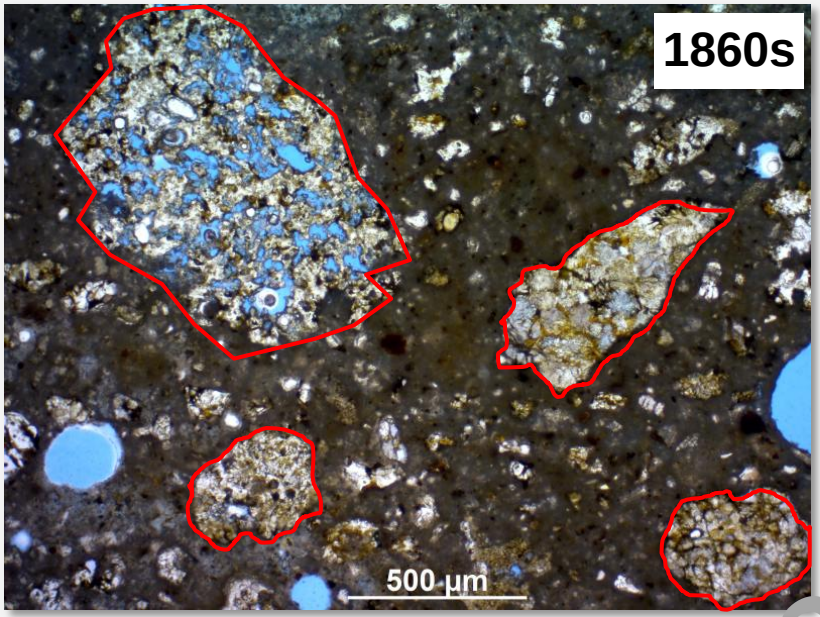
Macroscopic appearence of historical Portland cement

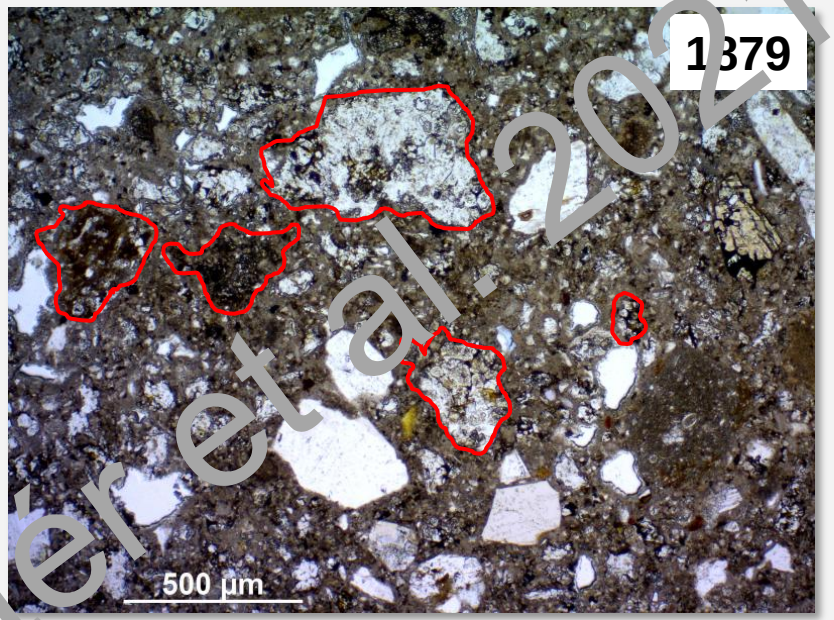


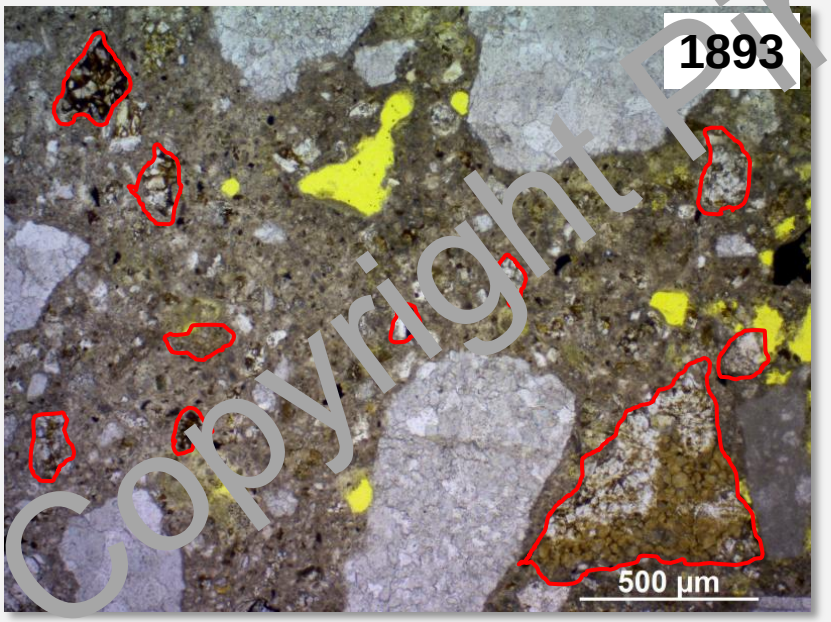


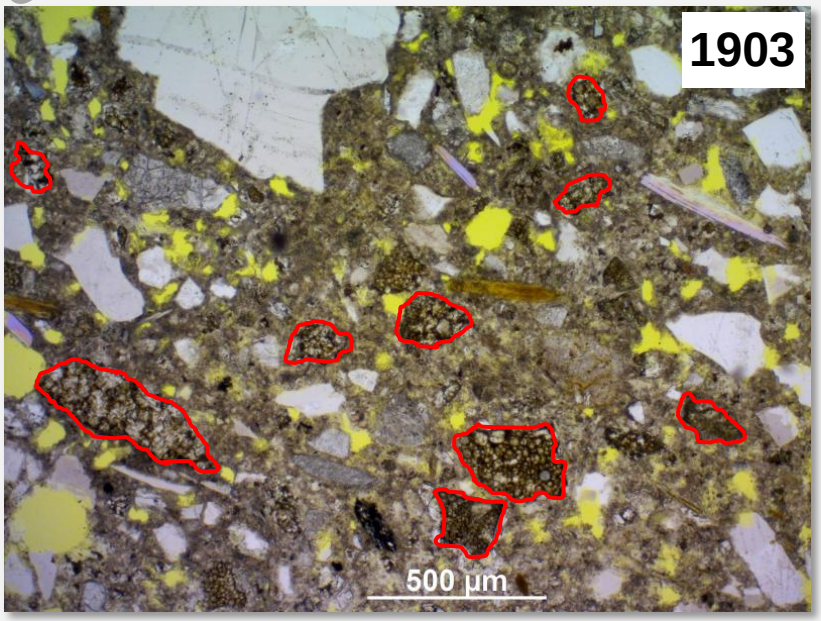
1907

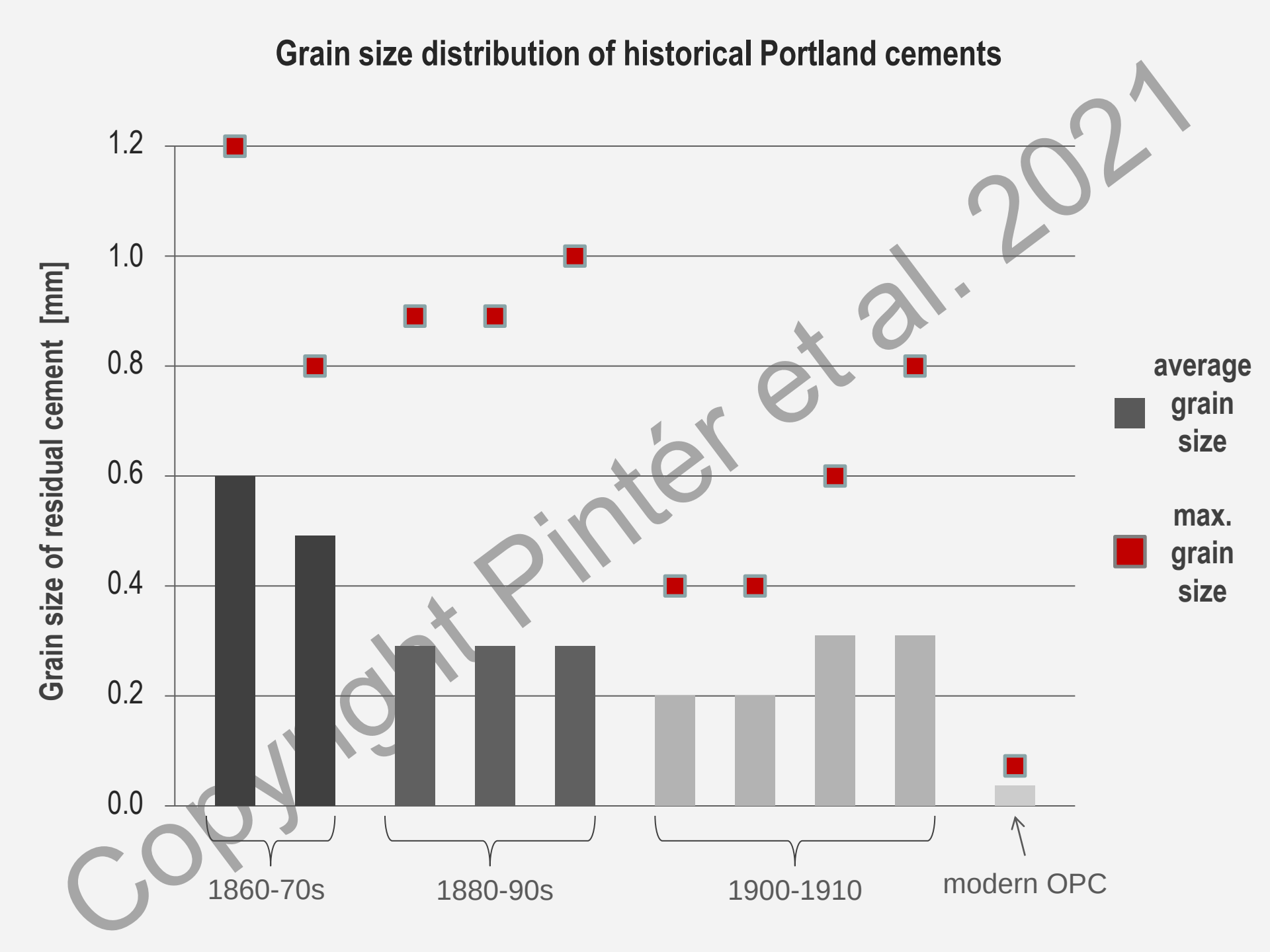
Appearance of historical Portland cement in the optical microscope










Grain size distribution of historical Portland cements
Grain size of residual cement [mm]
1.2
1.0
0.8
0.6
0.4
0.2
0.0
average grain size
max. grain size
1860-70s
1880-90s
1900-1910
modern OPC
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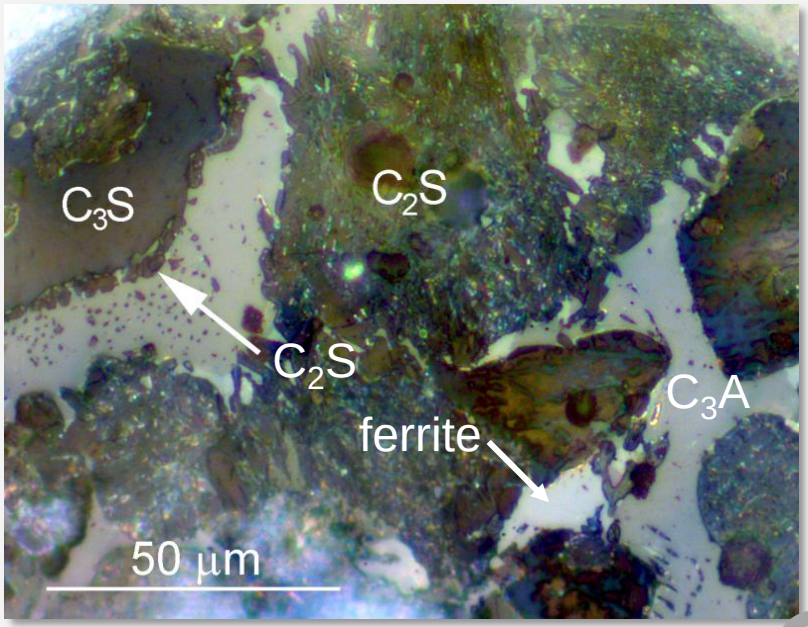
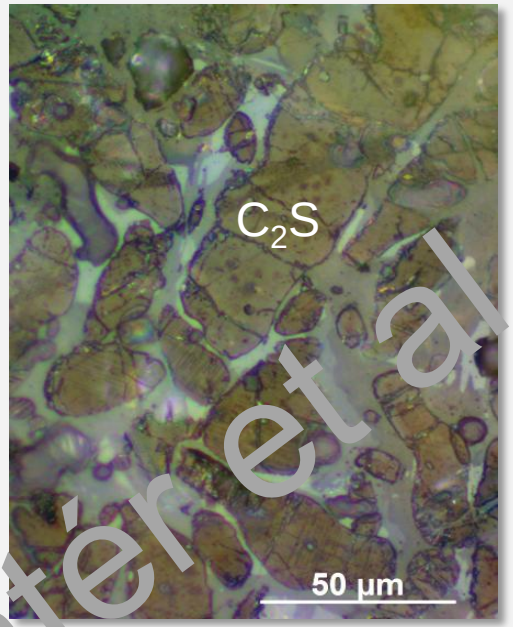
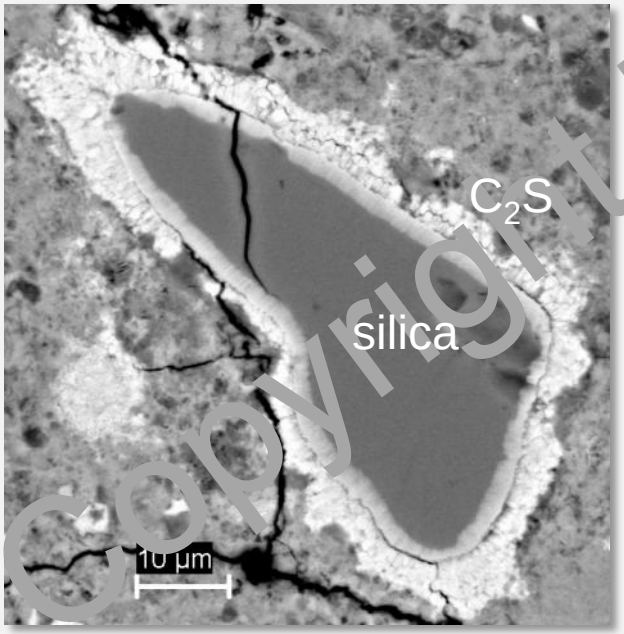
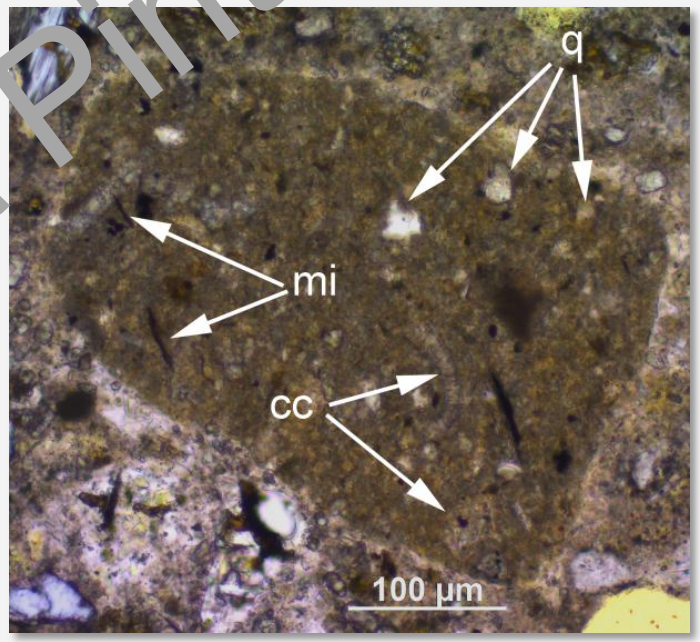
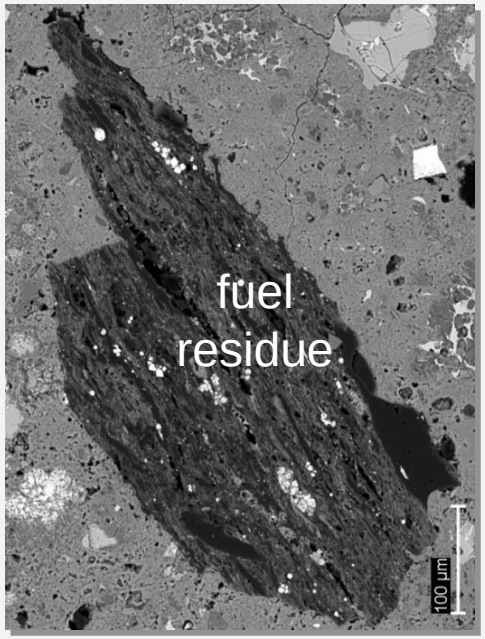
Mineralogy of Portland cements (1860-70s)



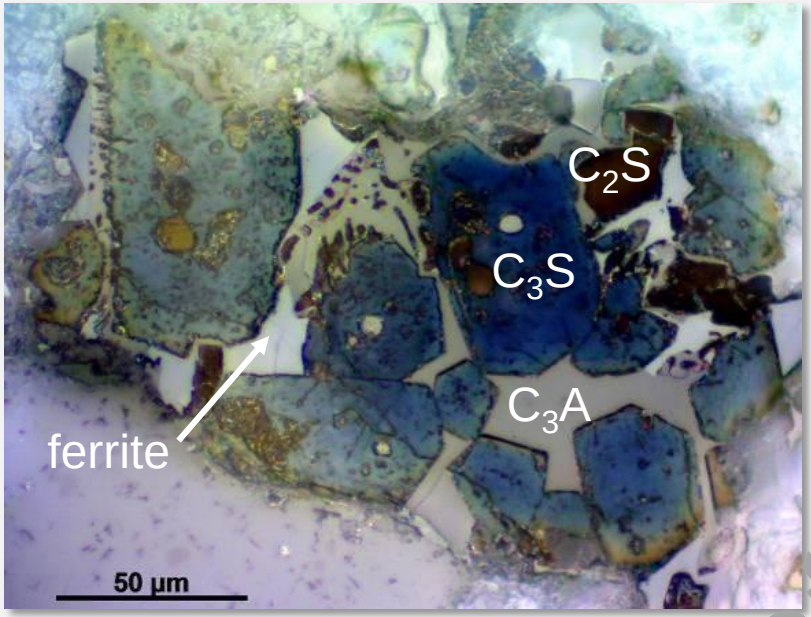


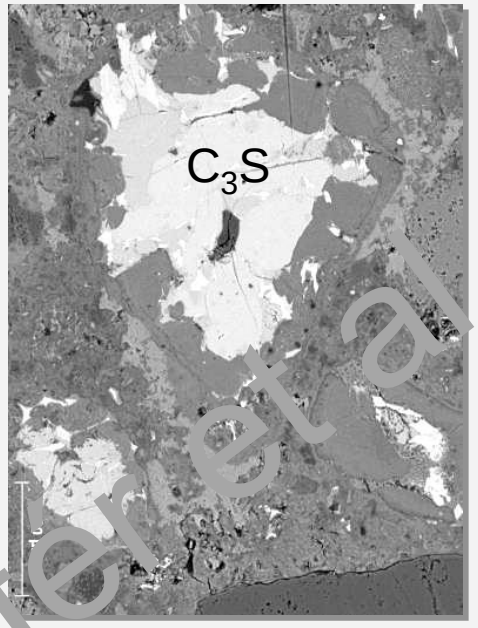


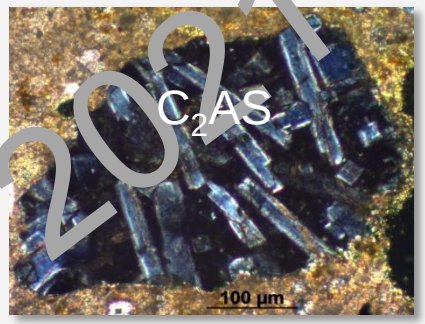


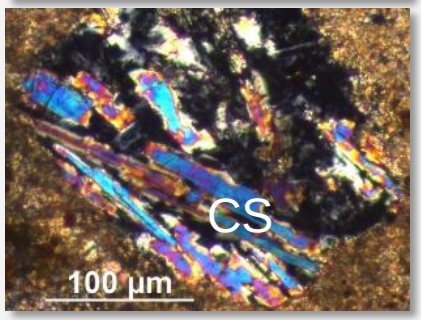


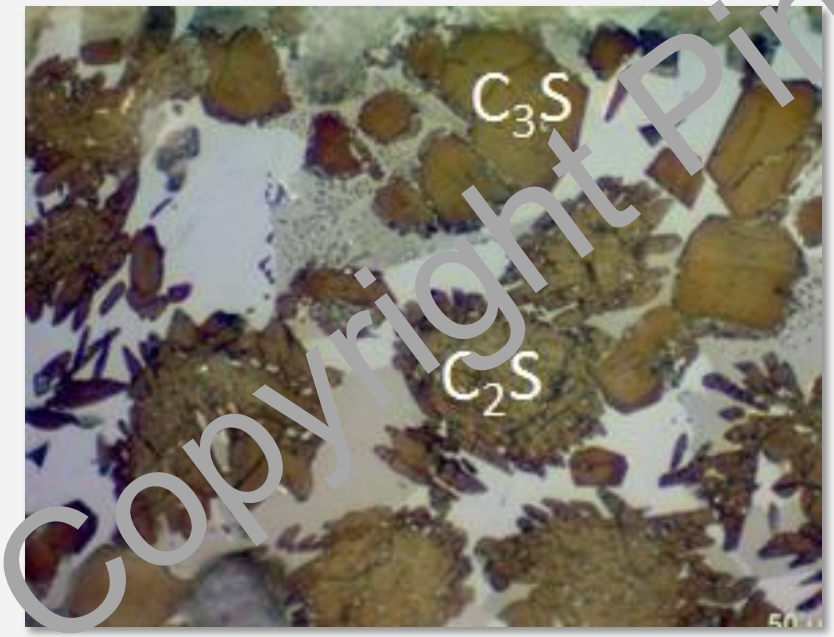
Mineralogy of Portland cements (1880-90s)

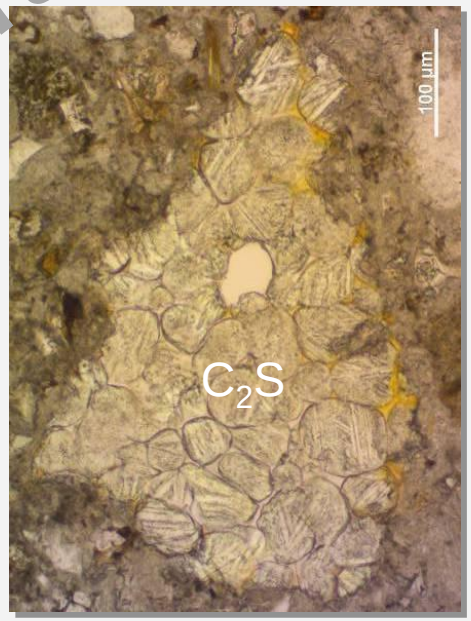


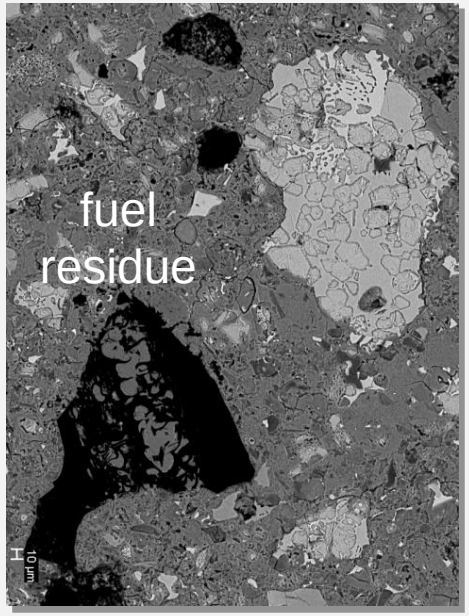




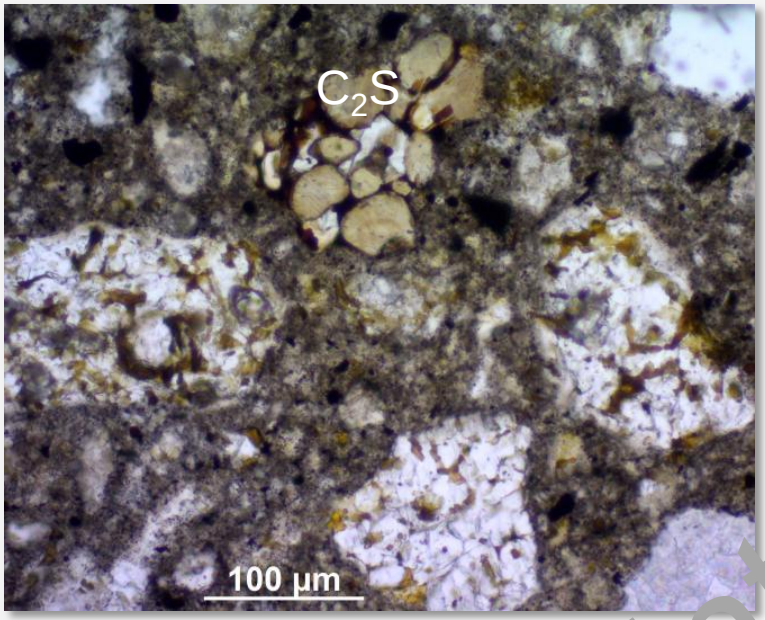


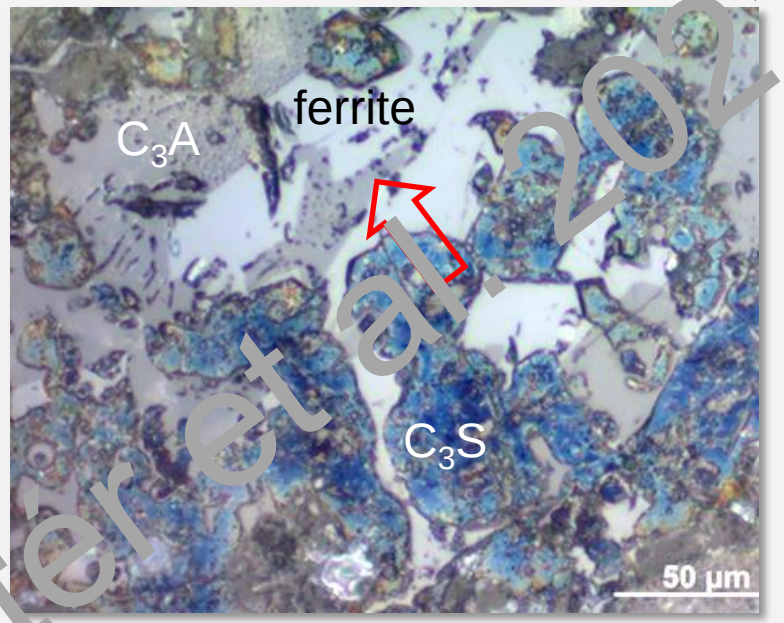


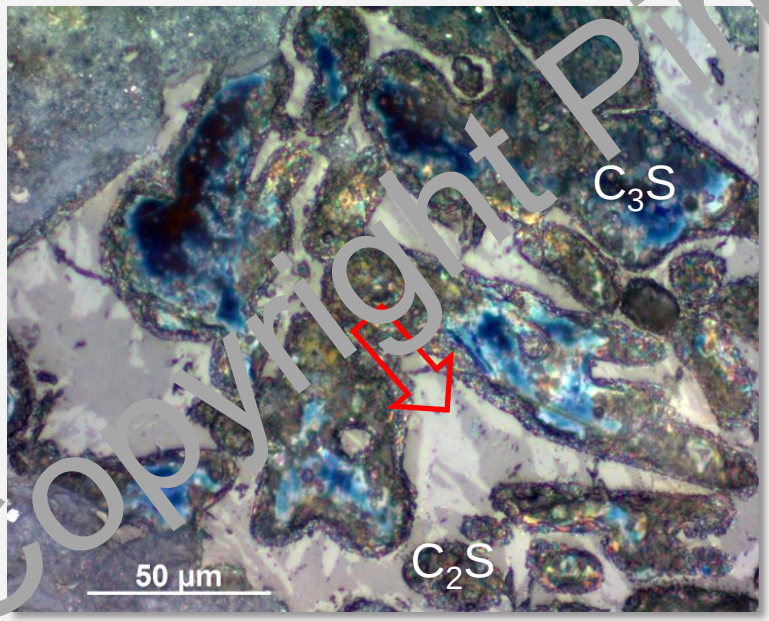


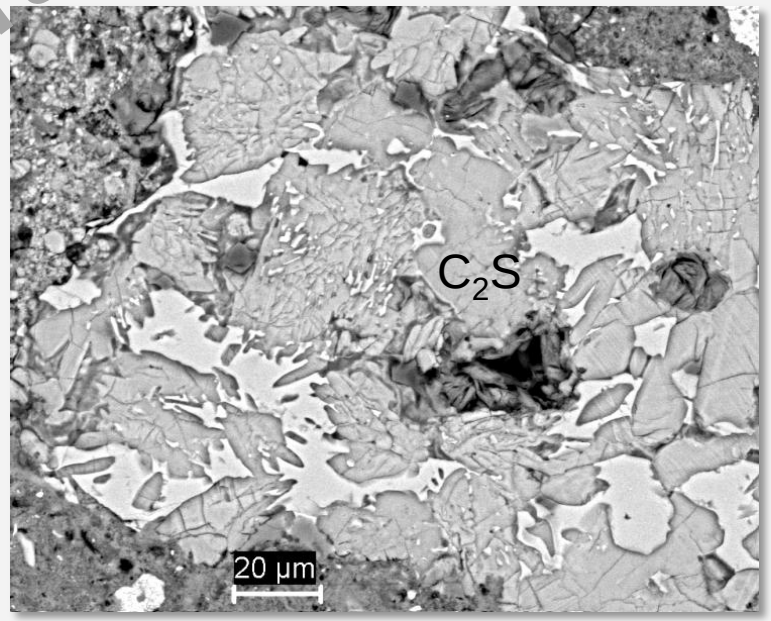


Mineralogy of Portland cements (early 1900s)

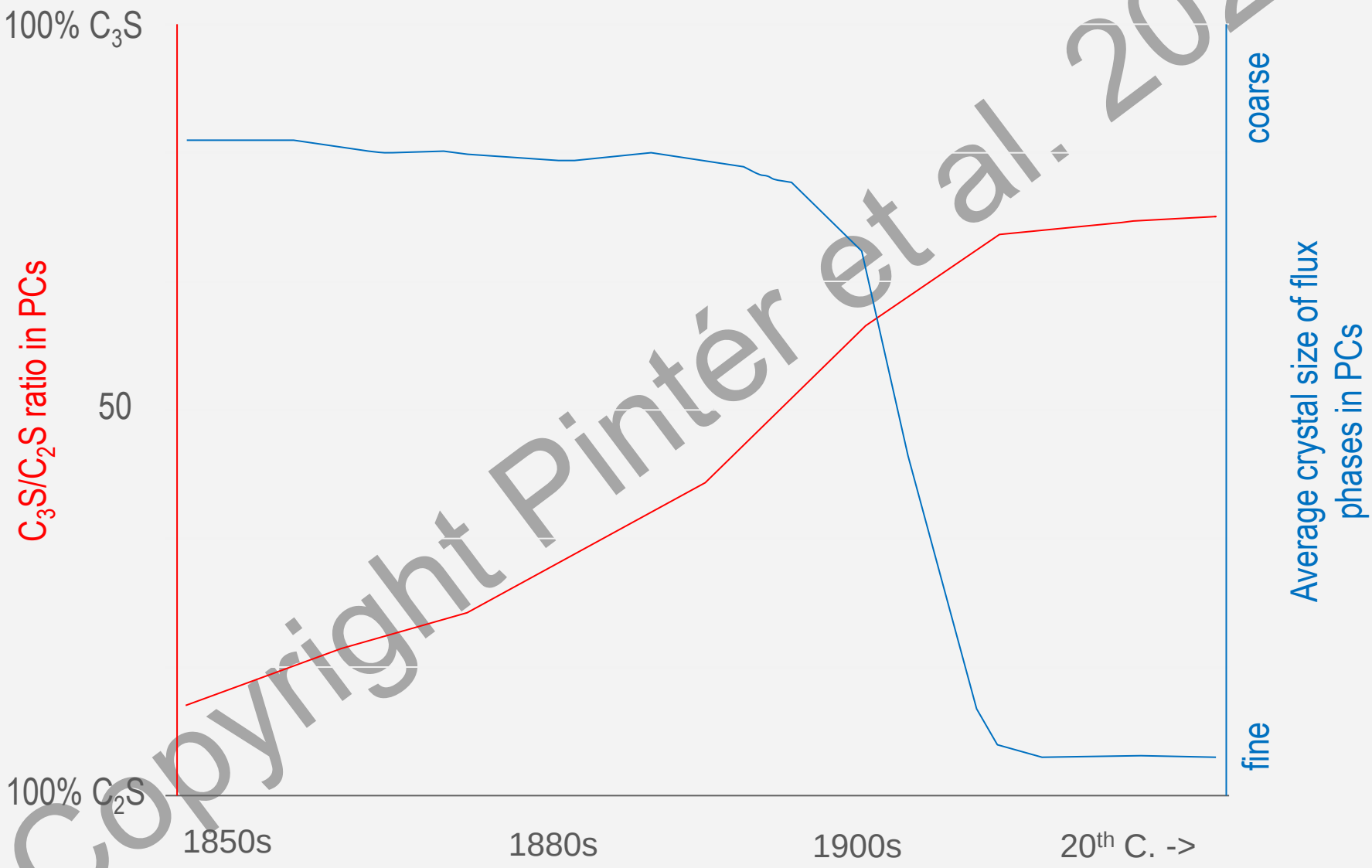




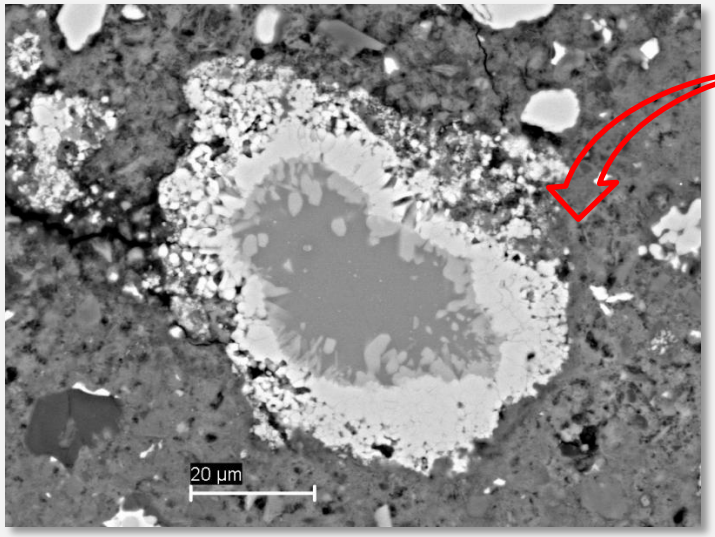


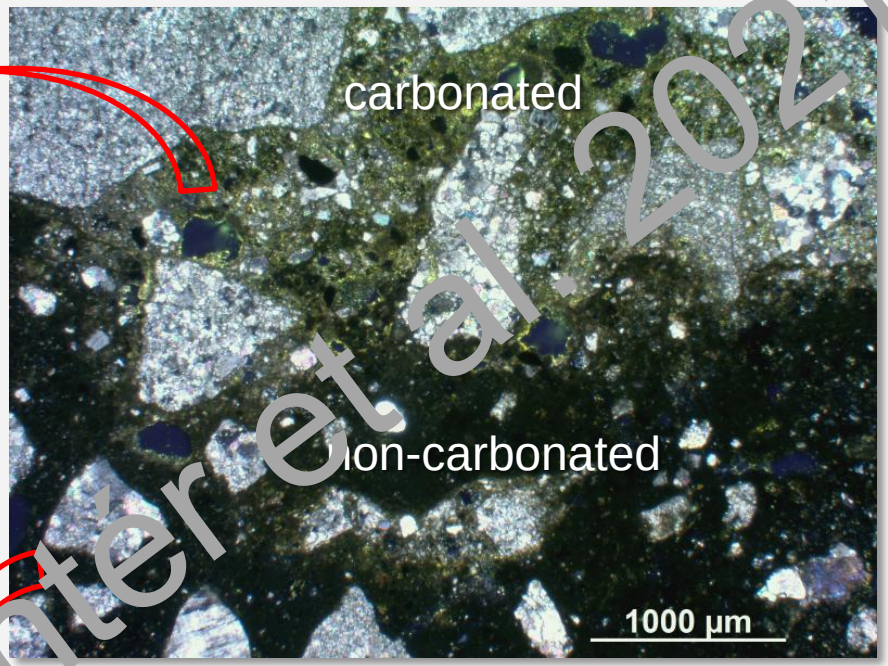


Ratio of calcium silicates and the average grain size of flux phases in PCs



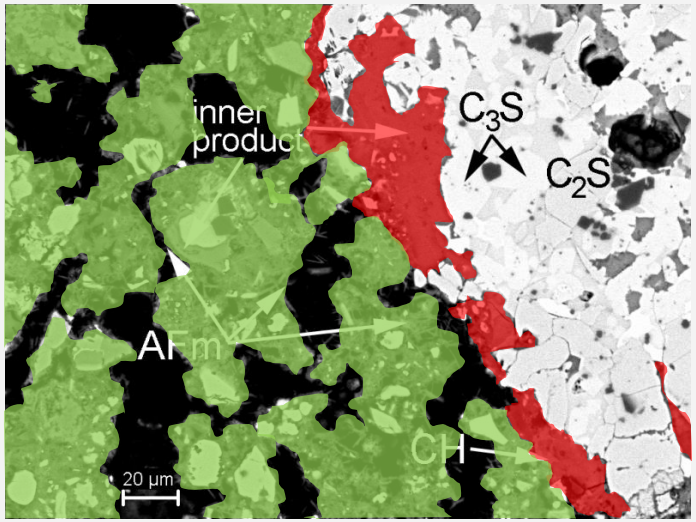
Microstructure and hydration products



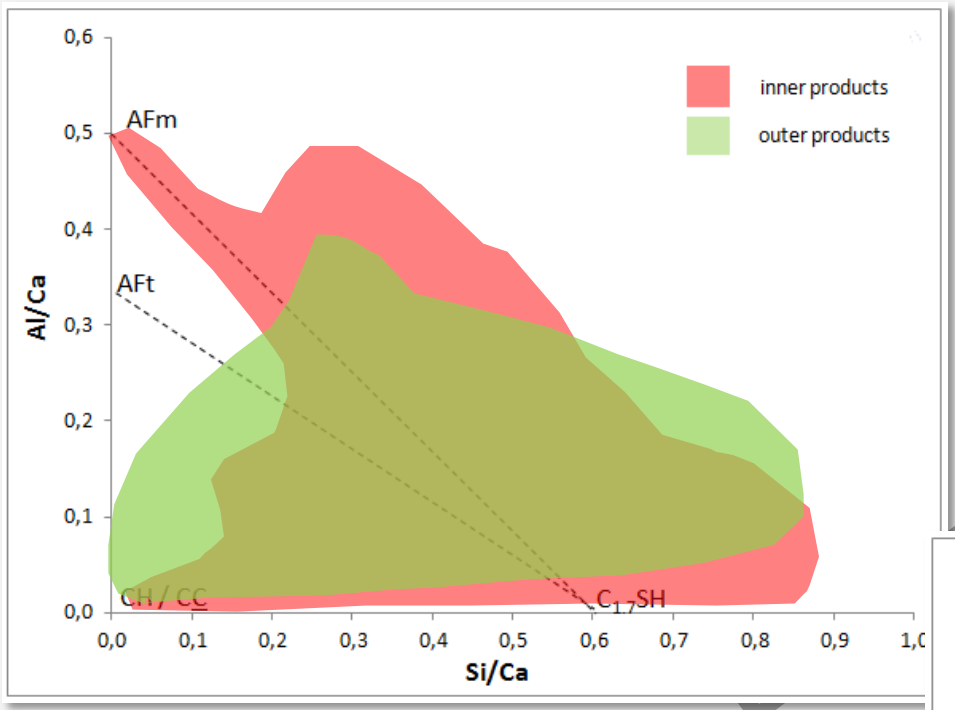


- SEM-EDS spot measurements on non-carbonated binder portions
- atomic ratios of Ca, Si, Al and S of inner and outer hydration products ->

Presence and distribution of C-S-H, AFt and AFm

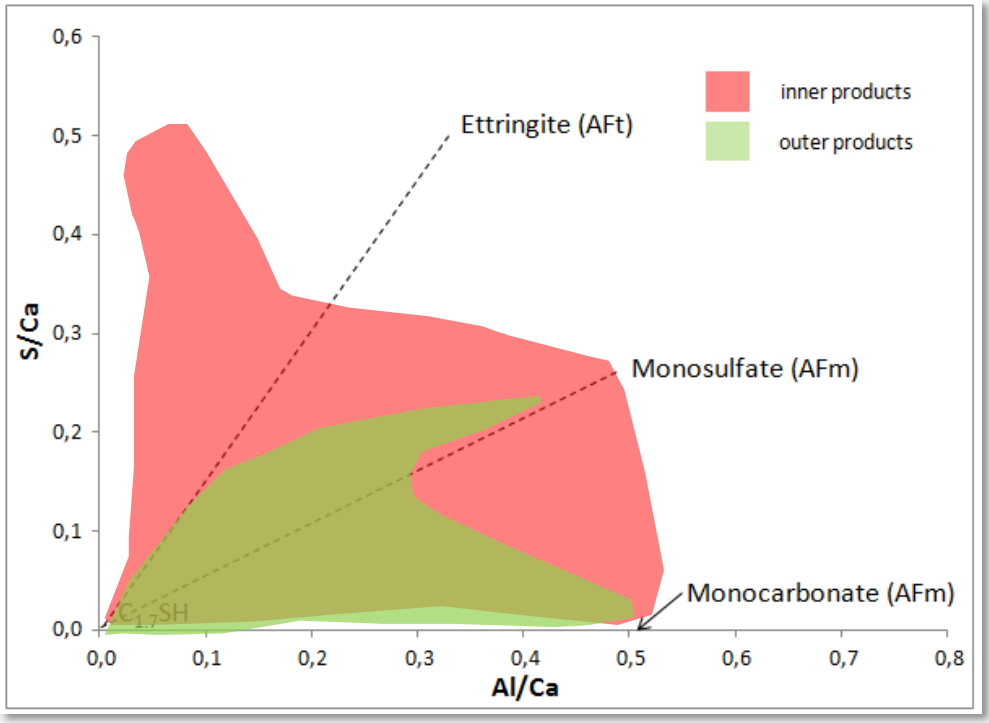


Development of hydration products in PCs from 1865-1871

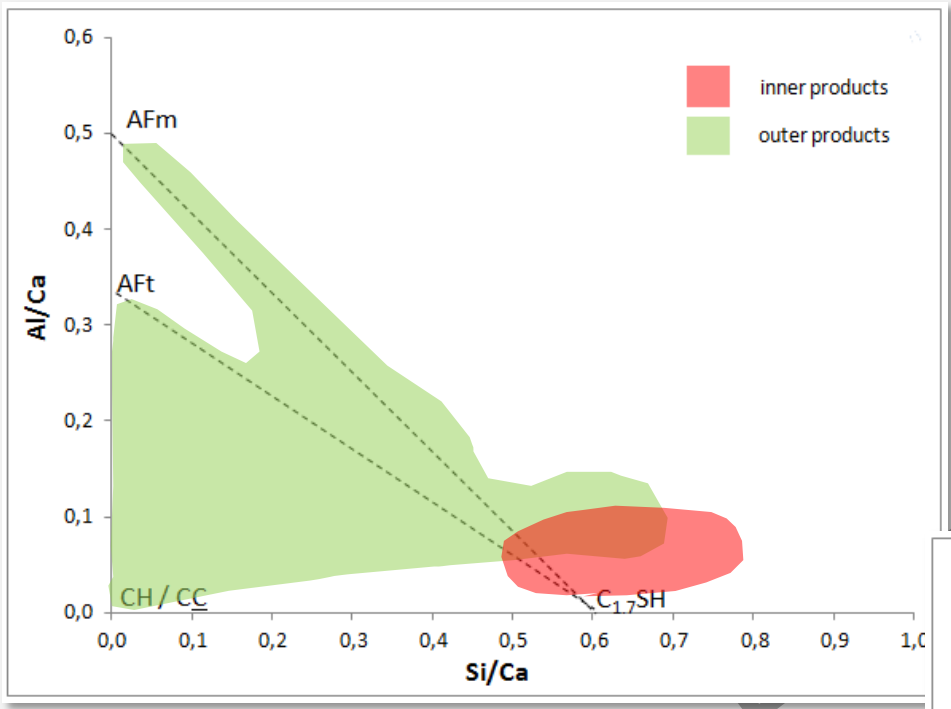


- due to partial carbonation and heterogeneous materials no clear difference between IP and OP
- OP are relatively poor in sulphate → lack of S in the early stage of hydration → (probably) no Ca-sulphate as a retarder

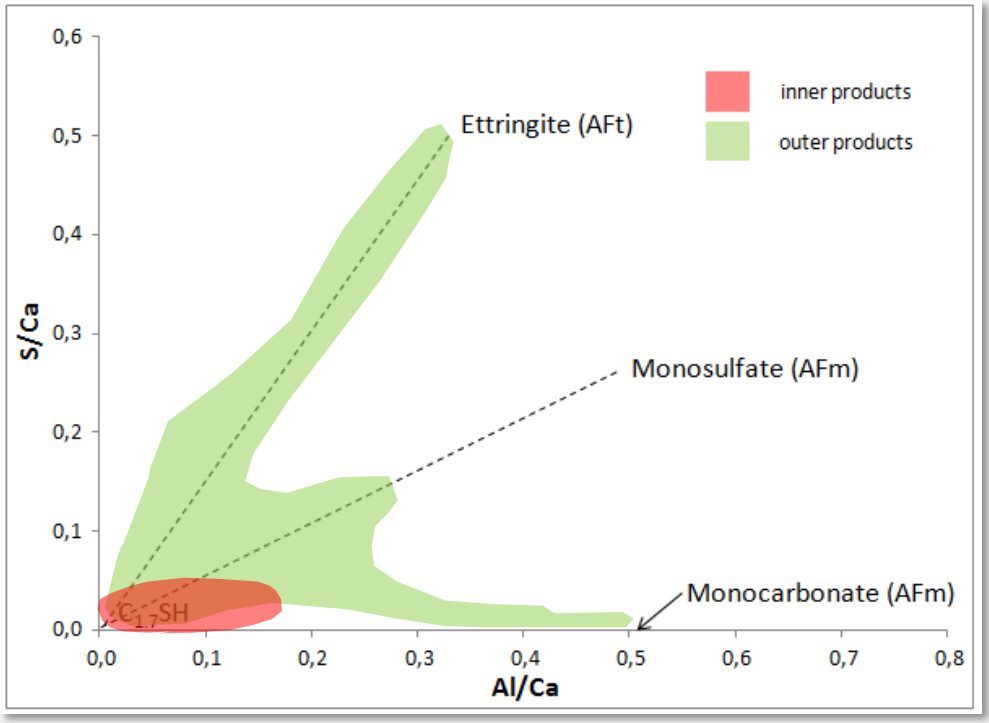
- sulphate-bearing hydration products in the IP → sulphoaluminate/silicate phases in the cement formed during calcination



Development of hydration products in PCs from the 1890s and early 1900s



- distribution of hydration products similar to those of modern PC
- IP is made up of „pure“ C-S-H
- OP: different amounts of S-bearing hydration products → presumable use of Ca-sulphate as setting retarder



CONCLUSIONS