# Bornholm Cement

A Danish example of Roman Cement

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# Bornholm Cement

Trade name of several types of Natural Cement (Roman Cement) fabricated by burning impure limestone from the Danish Island *Bornholm*.

Product description:
Yellowish brown strongly hydraulic lime (Natural Cement) that when hardened gives a reddish to chocolate brown mortar

Can not be slaked, contains free lime

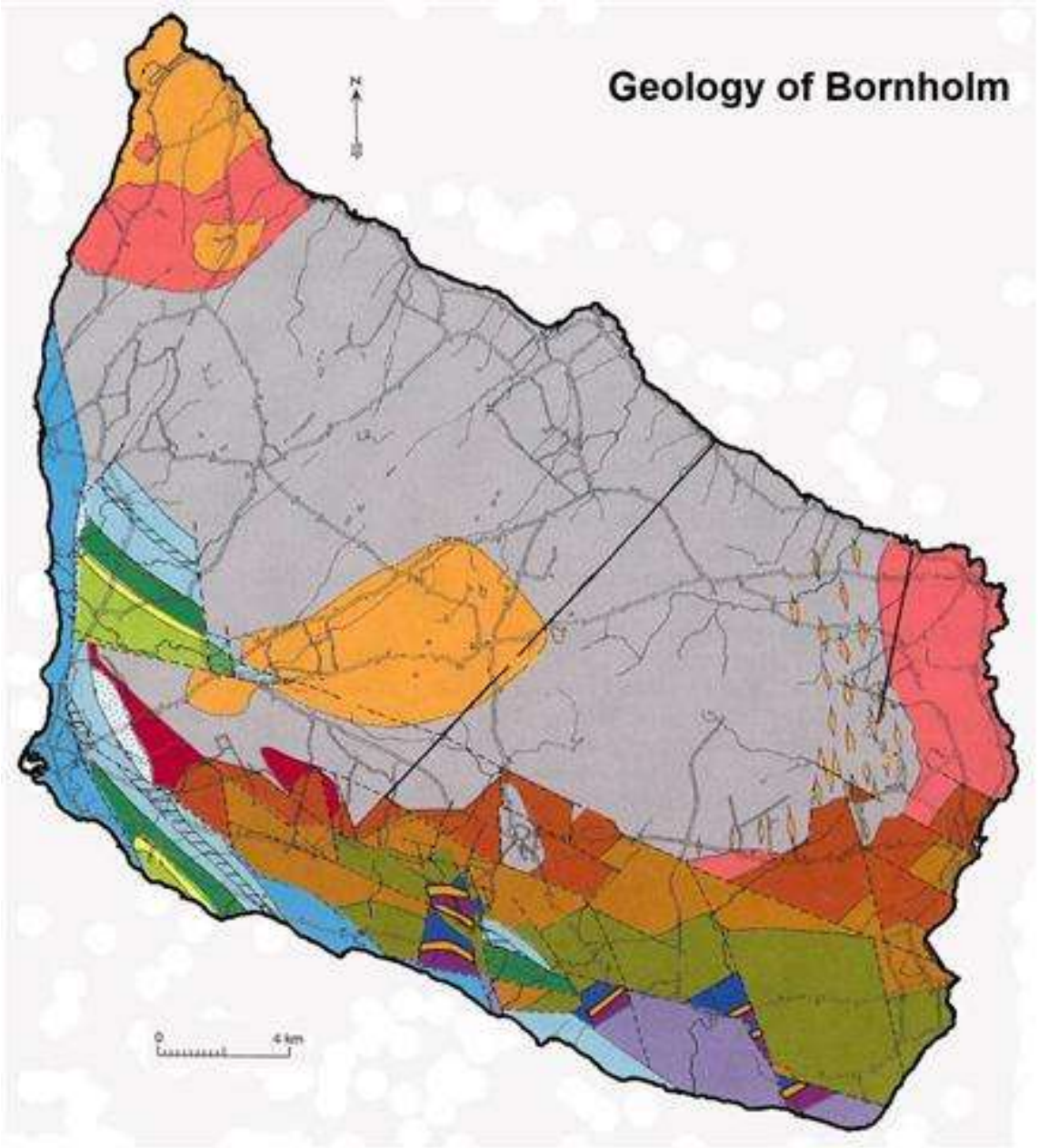
# Bornholm Cement

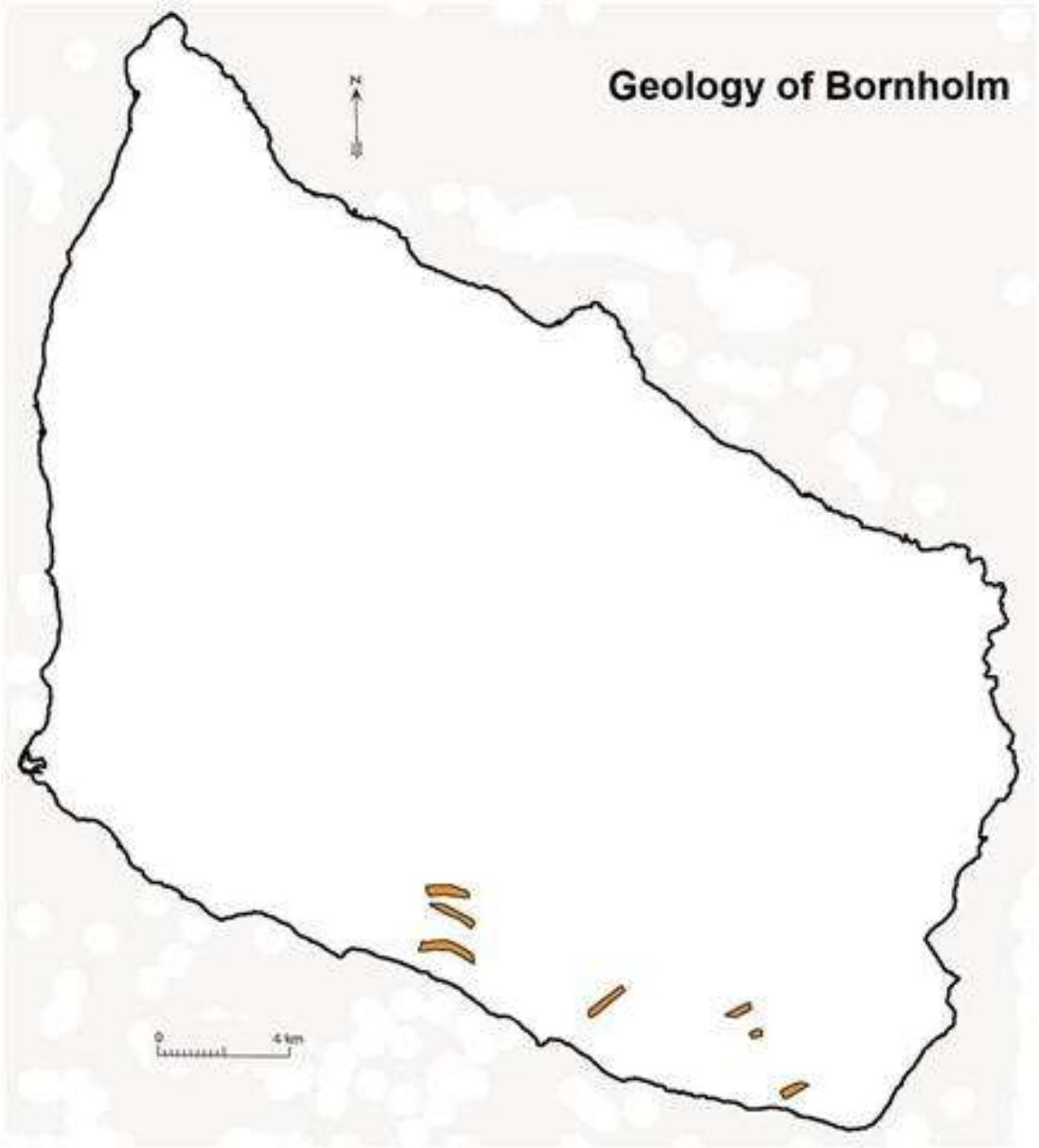
I will tell you about:

- The raw materials that were used for the cement
- The cement plants that fabricated the cement
- The physical and chemical properties of the cement
- Thin section analysis of mortars made from the cement
- Examples of buildings where the cement has been used
- But first – a little about *Bornholm*

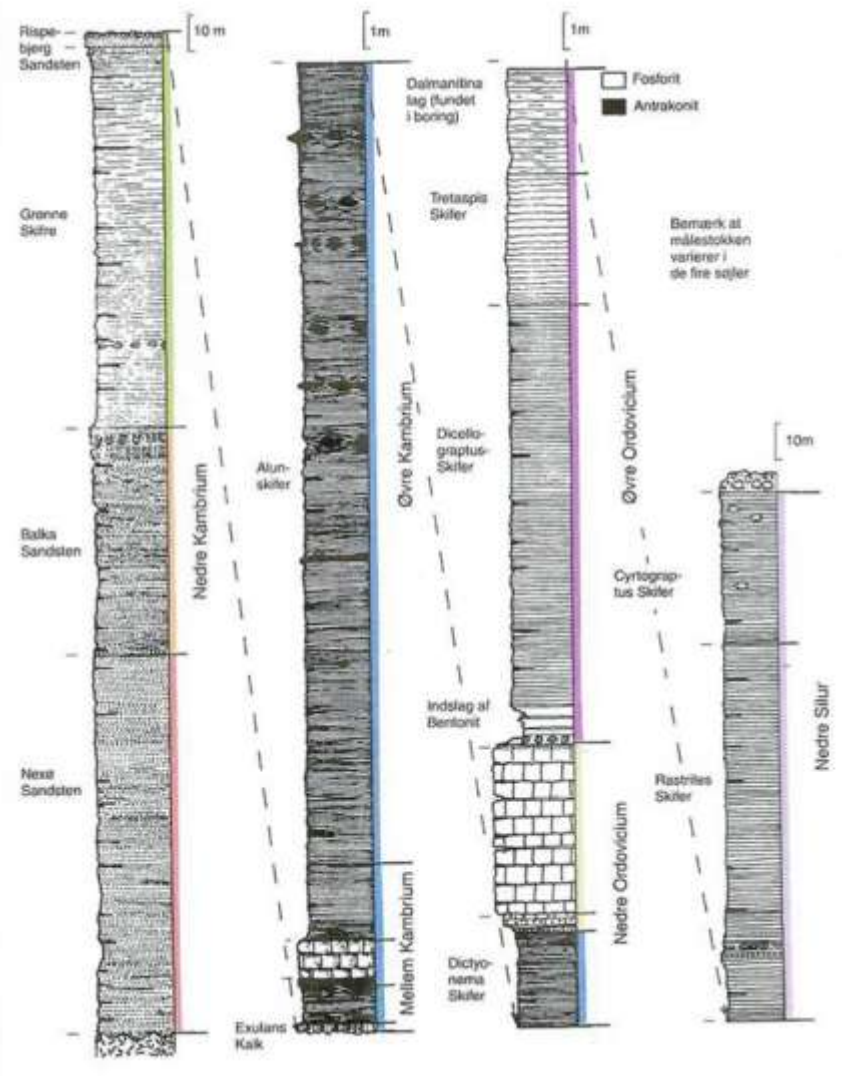
# Bornholm

# Bornholm

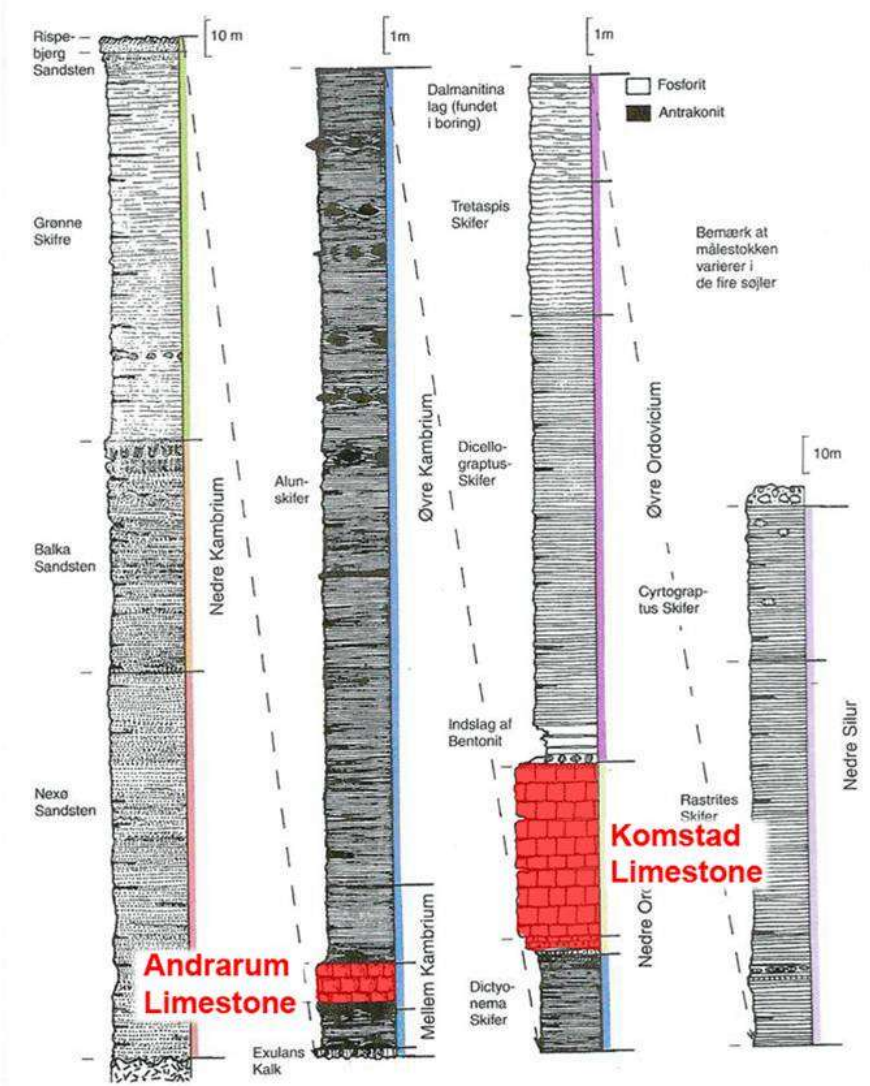

Geology of Bornholm
N
0
4 km


Geology of Bornholm
N
0
4 km

# Raw materials



# Raw materials



# Raw materials

## Andrarum Limestone

*(»Lower cement stone«,* only used at a single cement plant)

Age: Middle Cambrian (approx. 530 mill. year)

Layer thickness: 80 cm

Two lithological types:

A) Dark grey, fine grained limestone with a content of clay and organic material

B) Light grey, more coarse grained limestone with grains quartz (silica) and glauconite (clay)

Minor components are Iron sulphide ($FeS_2$) and Phosphorite (rock type rich in the phosphorous mineral Apatite).

Clay content: approx. 20-25%

Lime content: approx. 75 – 80%

Location of quarry: Along the small stream Øleåen

# Raw materials

Komstad Limestone *(»Orthoceratite Limestone«)*
*(»Upper cement stone«,* used at most of the cement plants)

Age: Lower Ordovician (approx. 490 mill. year)

Layer thickness: 4 – 5 m

Light grey to black, fine grained limestone with content of clay, quartz (silica), and organic material

Minor components are Iron sulphide ($FeS_2$) and Phosphorite (rock type rich in the phosphorous mineral Apatite)

Clay content: approx. 10 – 15%

Lime content: approx. 85 – 90%

Location of quarry : Limensgade near the small stream Læsåen and at Skelbro

# Raw materials

Skelbro quarry: Komstad Limestone

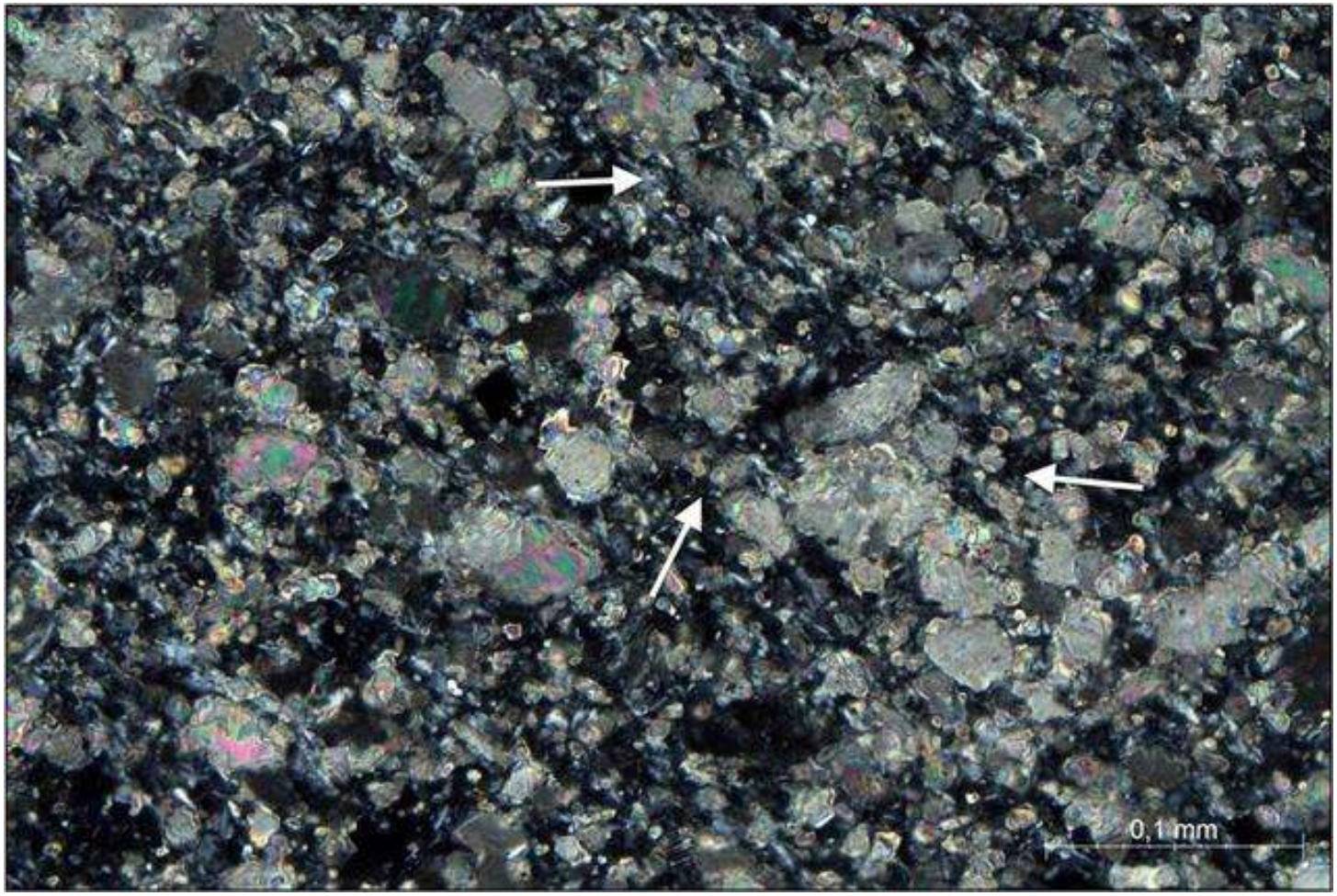
# Under the microscope – thin section analysis

Structure and mineralogy
of Komstad Limestone


Komstad Limestone – crystals of calcite ($CaCO_3$)


Komstad Limestone – crystals of marcasite/pyrite ($FeS_2$)


Komstad Limestone – organic material




Komstad Limestone – clay minerals

# Raw materials

Anthraconite nodules *(»antrakonitboller«, »stinksten«, »orsten«)*

Middle – Upper Cambrian (approx. 500 - 530 mill. year)

Dimensions:
Up to 0,5 x 3 m

Black, often coarse grained limestone with high content of organic material

Lime content: 80 – 95%

Often with many fossils and high content of Iron sulphide ($FeS_2$)

# Raw materials

## Ironstone

Brown iron rich concretions of clay with high content of Iron sulphide (marcasite/pyrite) – sometimes as concretions of pure Iron sulphide

Size:  Typical 2 – 5 cm

Iron content:  In the order 20 – 50%

# Cement plants

Andrarum Limestone

- The Cement plant *Fortuna* at Borregaard near Rispebjerg in Pedersker.
  1846 – 1910 (1915)

  Raw material:  Andrarum Limestone , anthraconite nodules, ironstone and alum shale

# Cement plants

Komstad Limestone

- *"Cement plant for burning of argillaceous Limestone at Limensgade"* ("Schors fabrik"). 1741 – 1765

- *"Aktieselskabet til Benyttelse af Limensgadens og Omegnens Mineralier"*
  *(The company for exploration of the minerals of Limensgadens and the sorrounding areas)* ("Hammes fabrik"). 1840 – 1850

- The Cement plant *Phønix* south of the town Rønne. 1841 – 1920?
  Raw material: Limestone from Limensgade and Ironstone from the coast of Bornholm

- *Frandsen & Meyers* Cement plant in Copenhagen. 1863-?
  Raw material: Limestone from Limensgade and Alum waste from Belgium

# Cement plants

Komstad Limestone

- Cement plant *Limensgade* at Risegård in Aaker. 1920 – 1941
  Raw material: Komstad Limestone from the Skelbro pit

- Cement plant *Haabet ("the hope").* 1858
  Raw material: Presumably Komstad Limestone from Limensgade

- Cement plant *Lykkens prøve ("the trial of fortune").* 1858
  Raw material: Presumably Komstad Limestone from Limensgade

- Cement plant *Godthaab ("good-hope").* 1858
  Raw material: Presumably Komstad Limestone from Limensgade

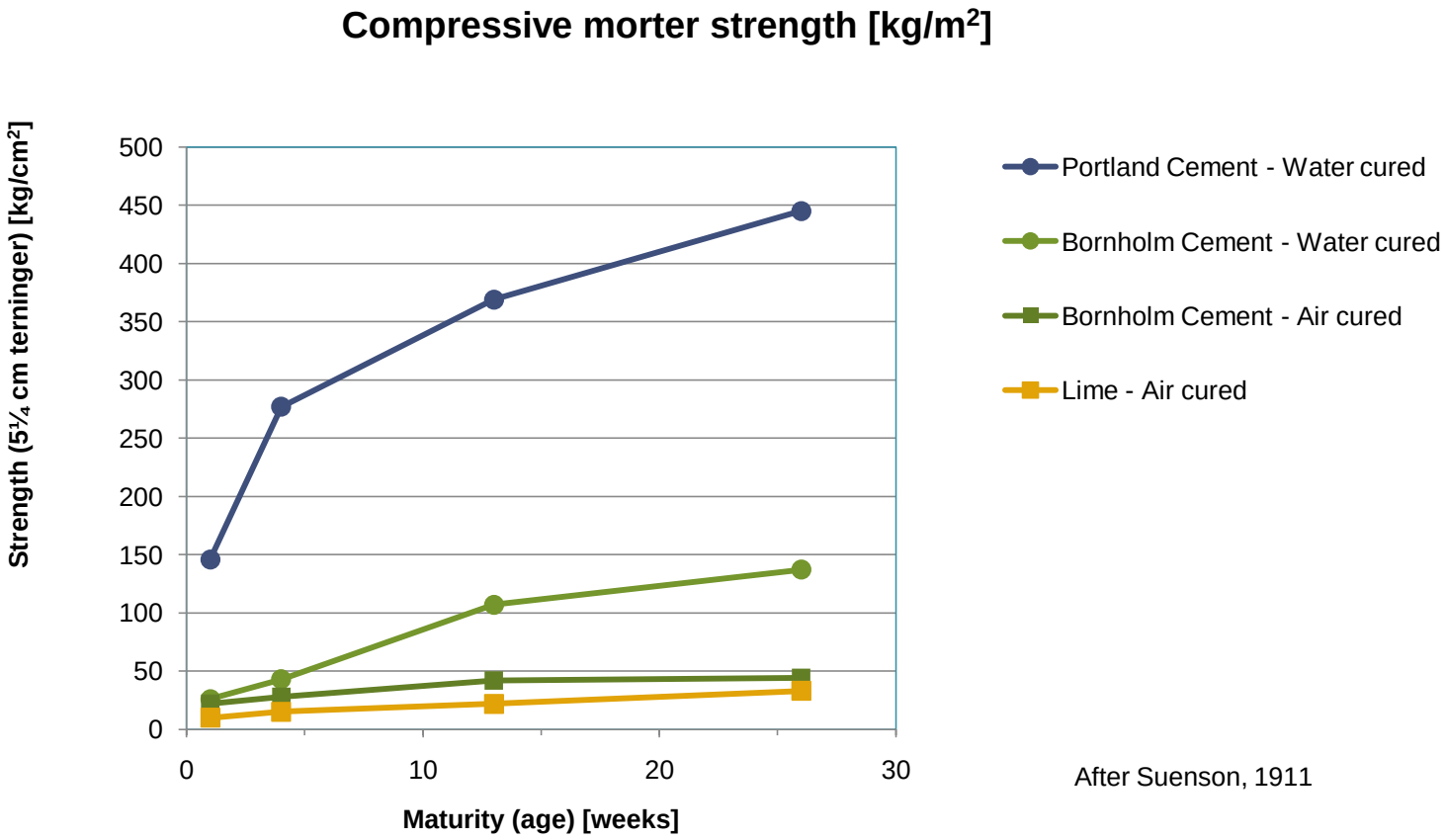
- Cement plant *Saga.* 1858
  Raw material: Presumably Komstad Limestone from Limensgade

# Bornholm Cement – main types

- Red Bornholm Cement
  Burned Limestone with addition of burned Ironstone

- Grey Bornholm Cement
  Burned Limestone with no addition

# Bornholm Cement - physical properties




After Suenson, 1911

# Bornholm Cement - physical properties

Bulk density,

| | |
|---|---|
| Loosely compacted: | 0,9 kg/liter |
| Compacted (shaked): | 1,3 kg/liter |

Grading (sieving analysis):

| | | |
|---|---|---|
| On 900 mesh sieve: | 22% | (particle size: > 0,222 mm) |
| On 4900 mesh sieve: | 38% | (particle size 0,090 – 0,222 mm) |
| Passed: | 40% | (particle size <0,09 mm) |

Setting time: 5 – 10 min

# Bornholm Cement – chemical composition

Sample taken in 1907 (after Suenson 1911):

| | |
|---|---|
| Soluble $SiO_2$: | 6,2% |
| Insoluble $SiO_2$ + remnants: | 44,6% |
| CaO: | 44,1% |
| $Al_2O_3$: | 2,0% |
| $Fe_2O_3$: | 1,7% |
| MgO: | 0,7% |
| $SO_3$: | 0,7% |
| Total | 100,0% |

# Thin section analysis

Bornholm Cement used in mortar – characteristics:

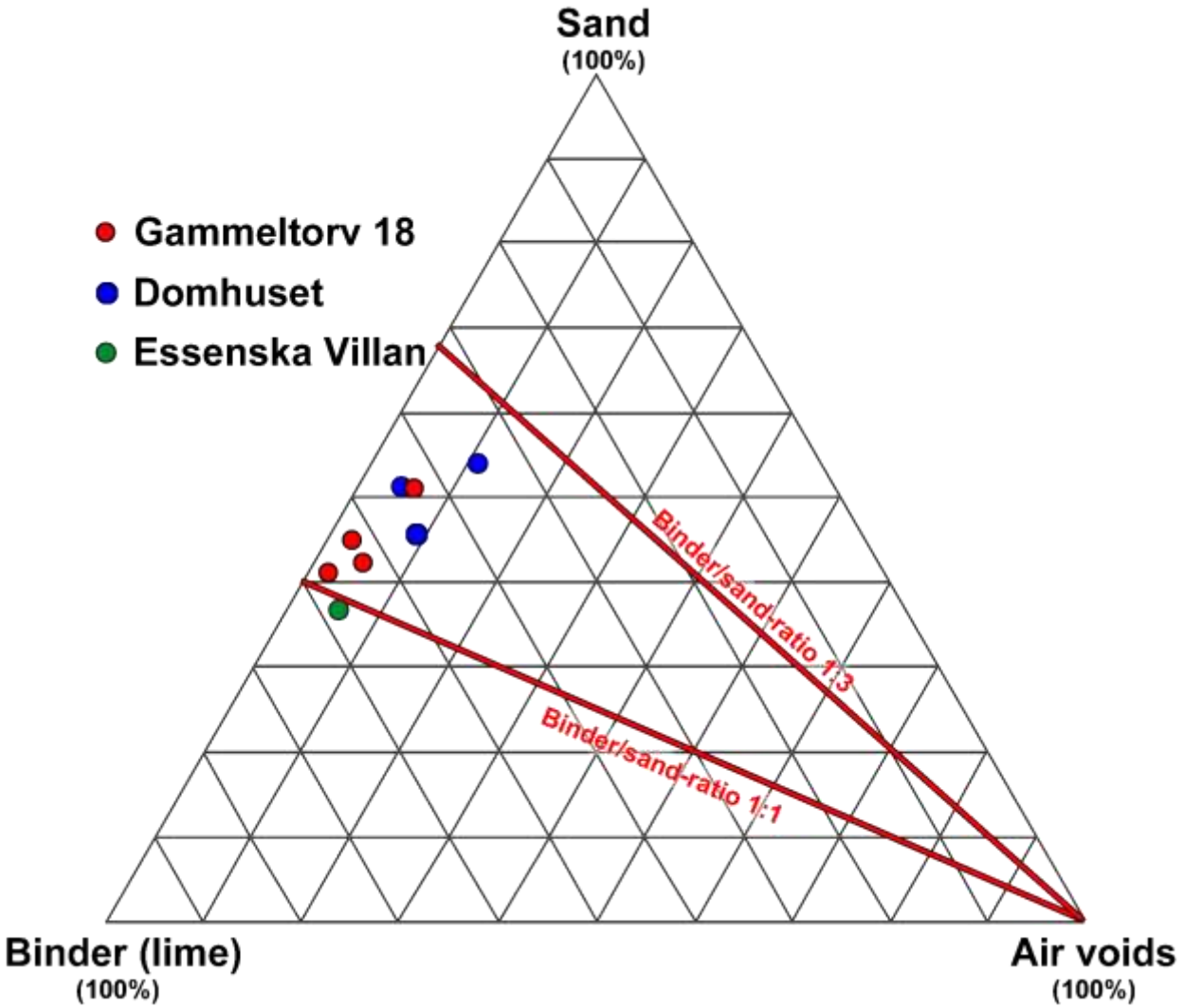
Binder/sand ratio:

Relatively Binder-rich (1:1 to 1:2)

Content of air voids:

Relatively low air content (2 – 10% )

# Thin section analysis

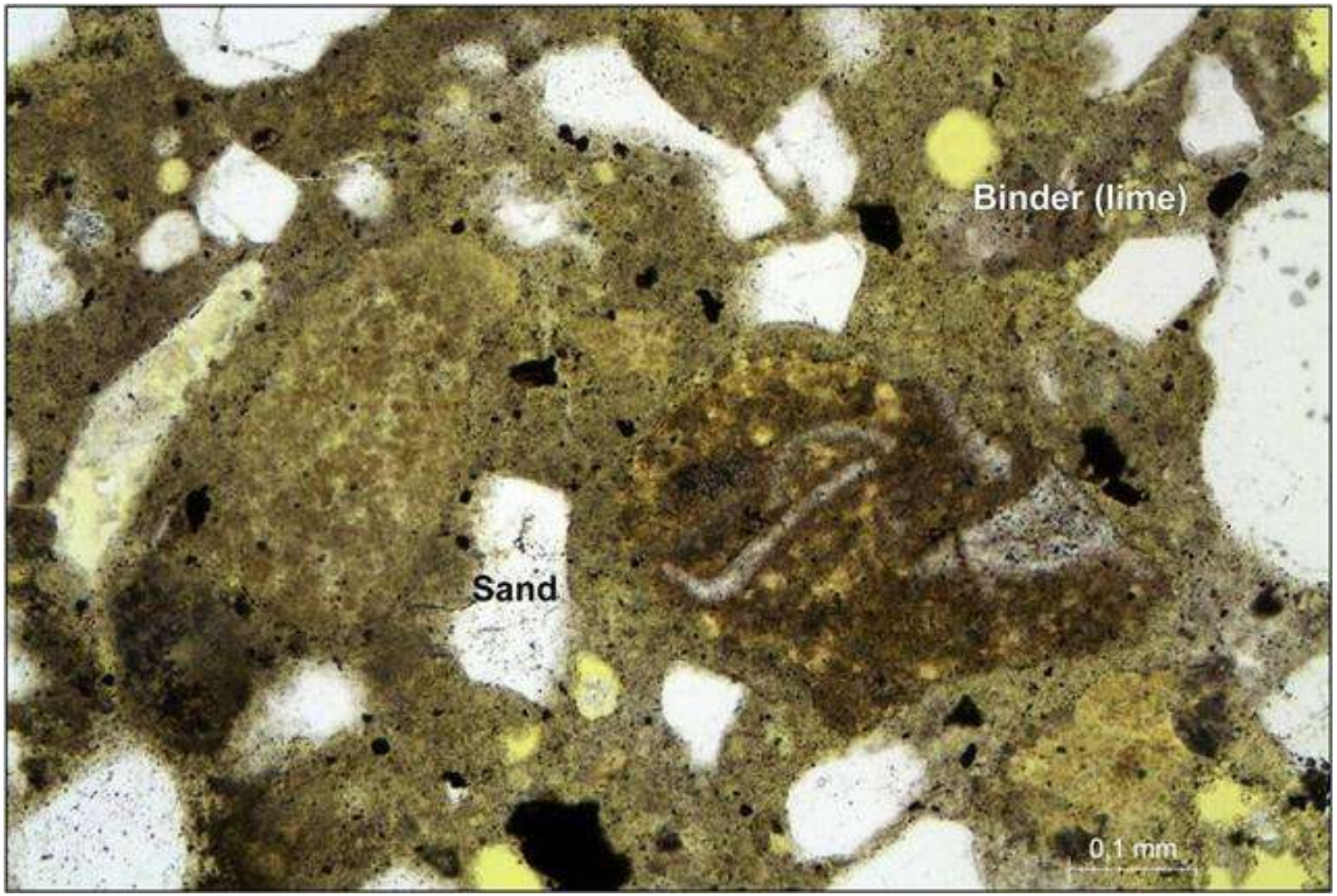


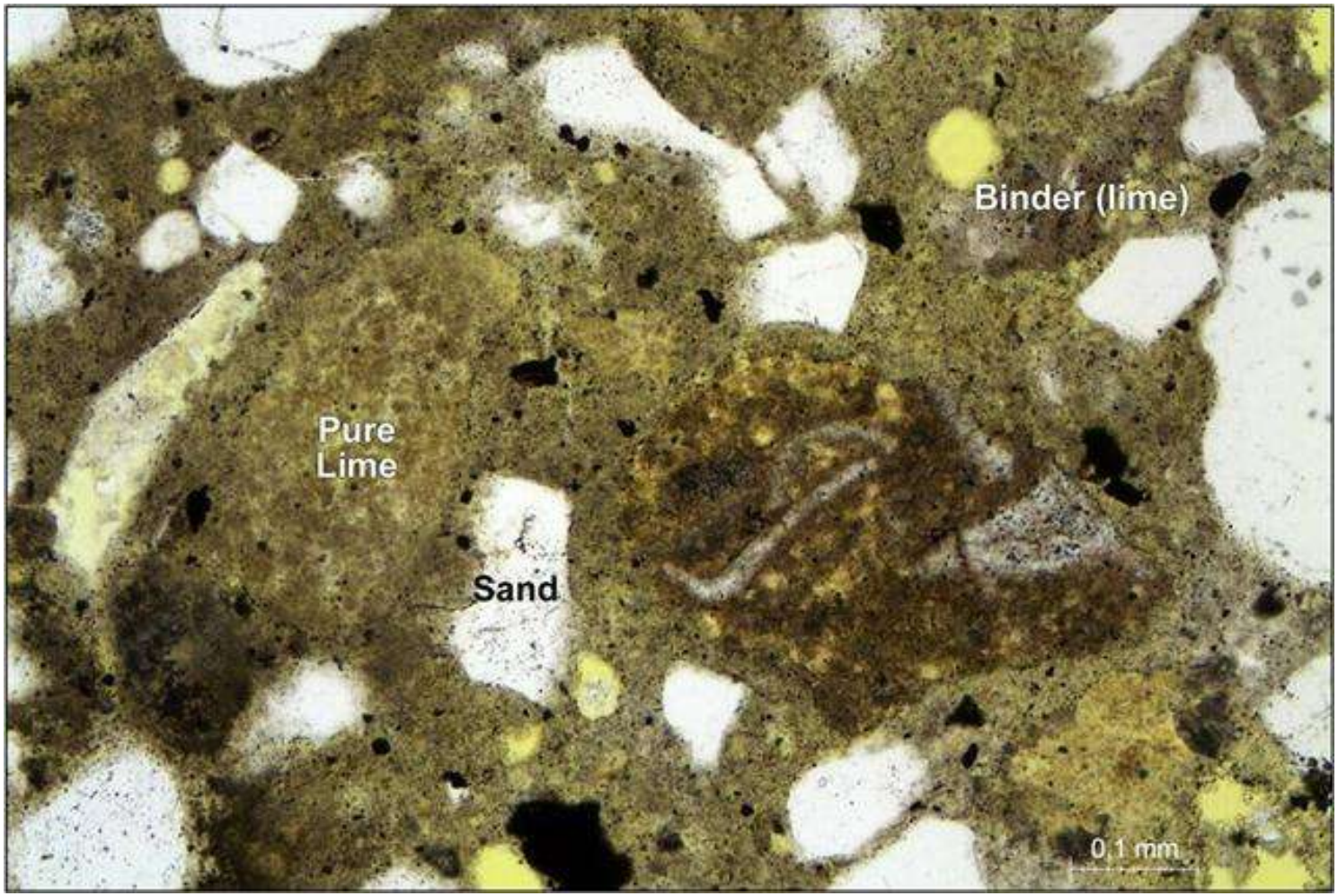
# Thin section analysis

Bornholm Cement used in mortar – characteristics:

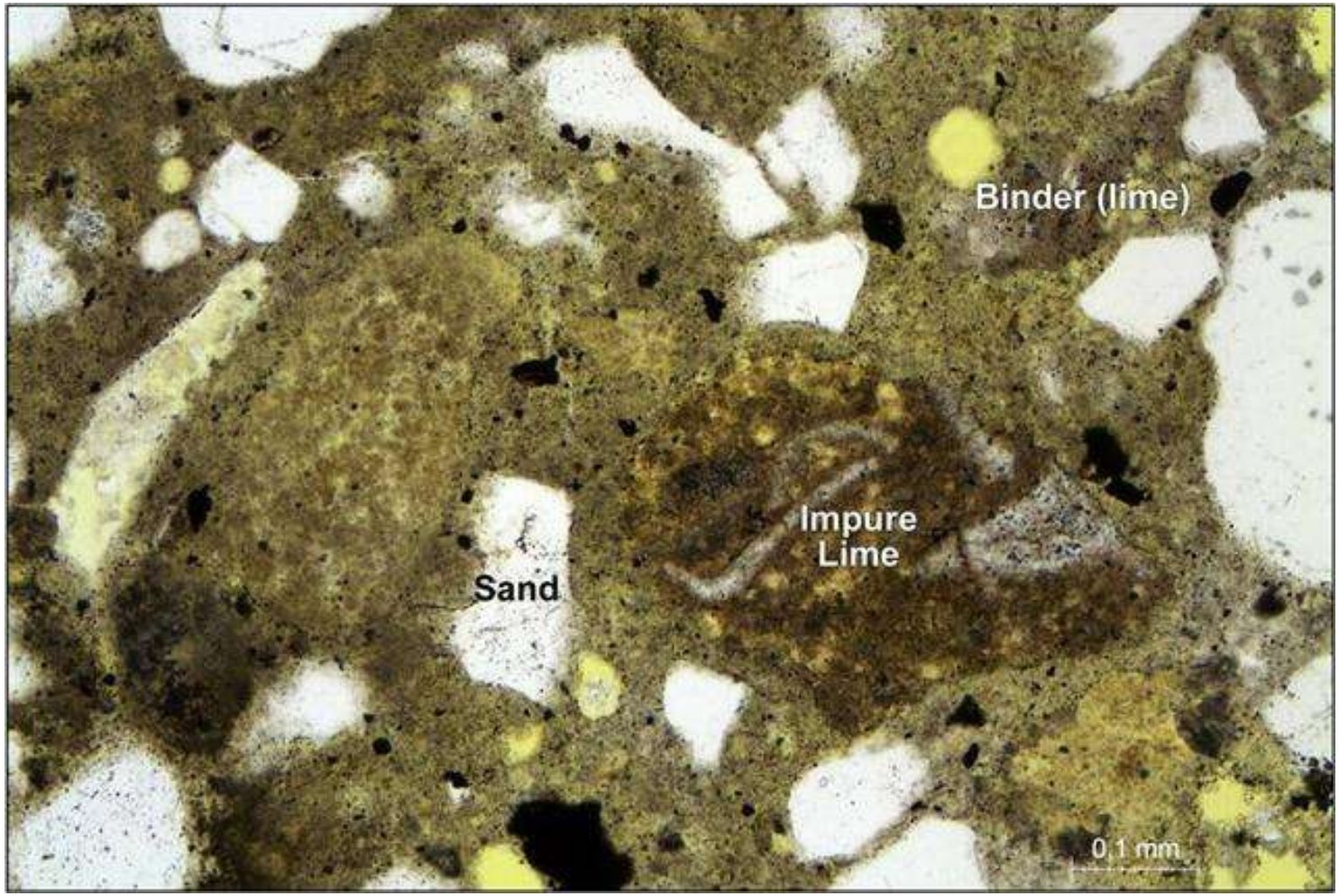
Binder (lime):

Inhomogeneous with many (typically 10 – 20% by volume) undispersed lumps and grains of the following types:

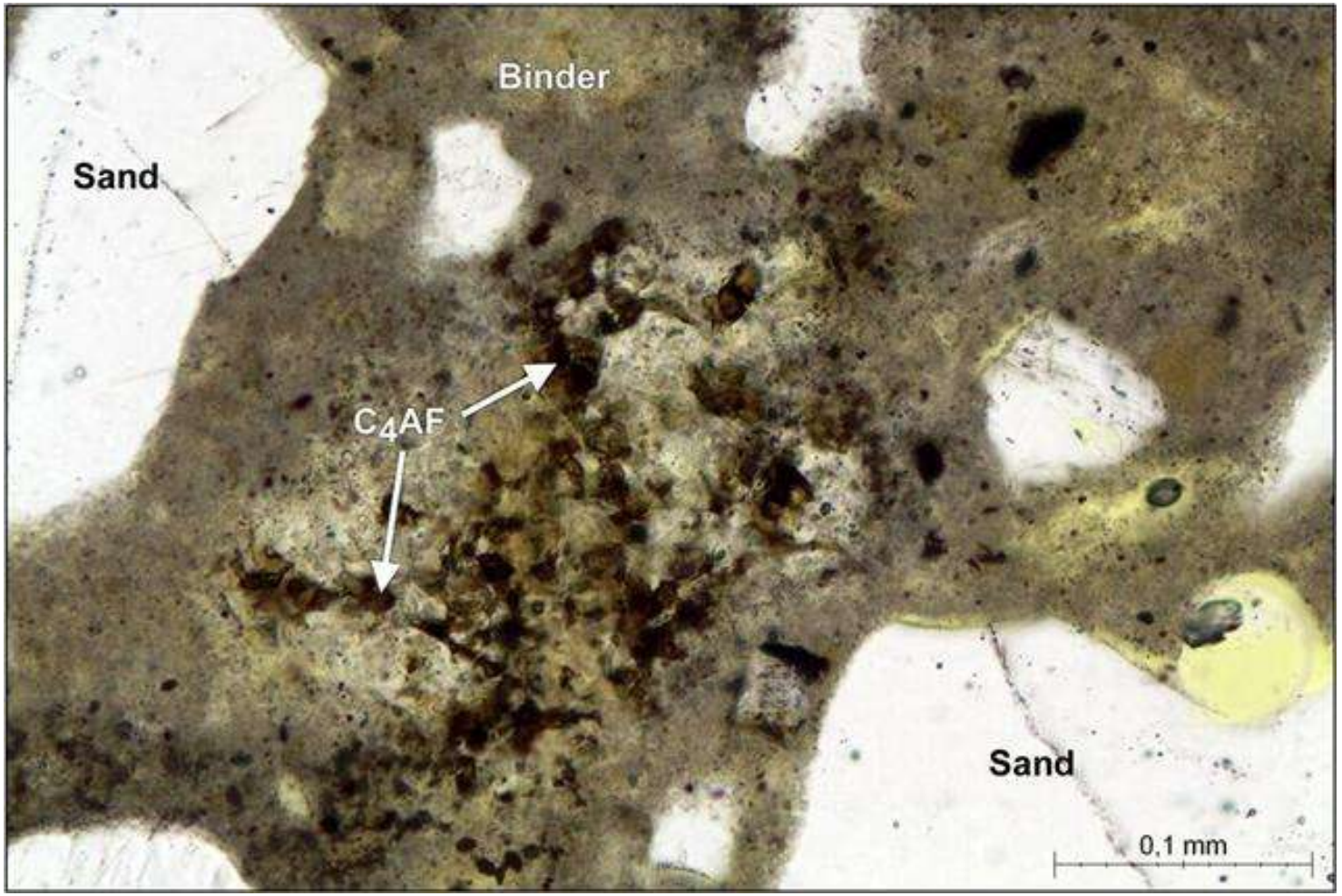

Binder (lime)
Sand
0.1 mm



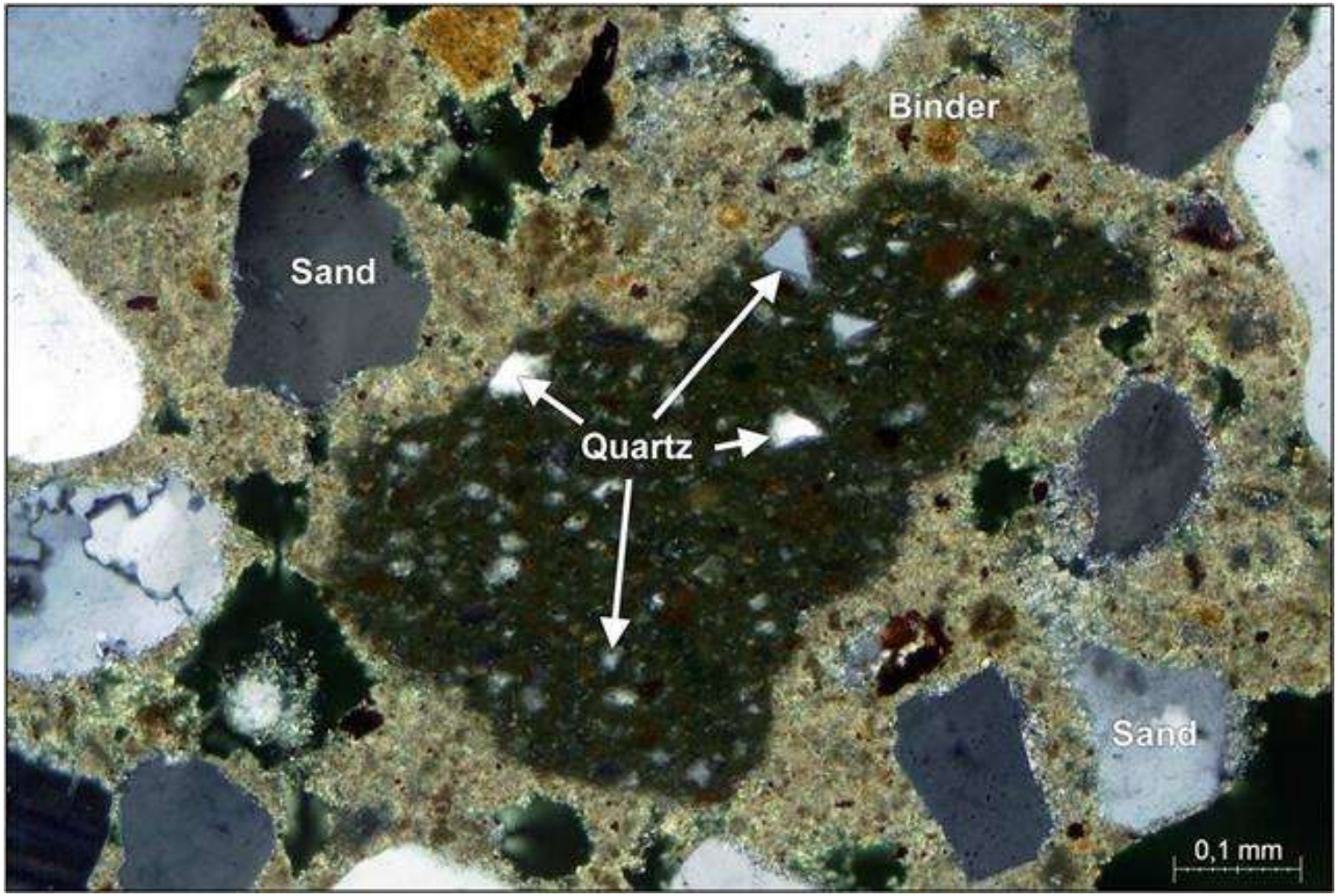

White lumps of pure lime with few impurities



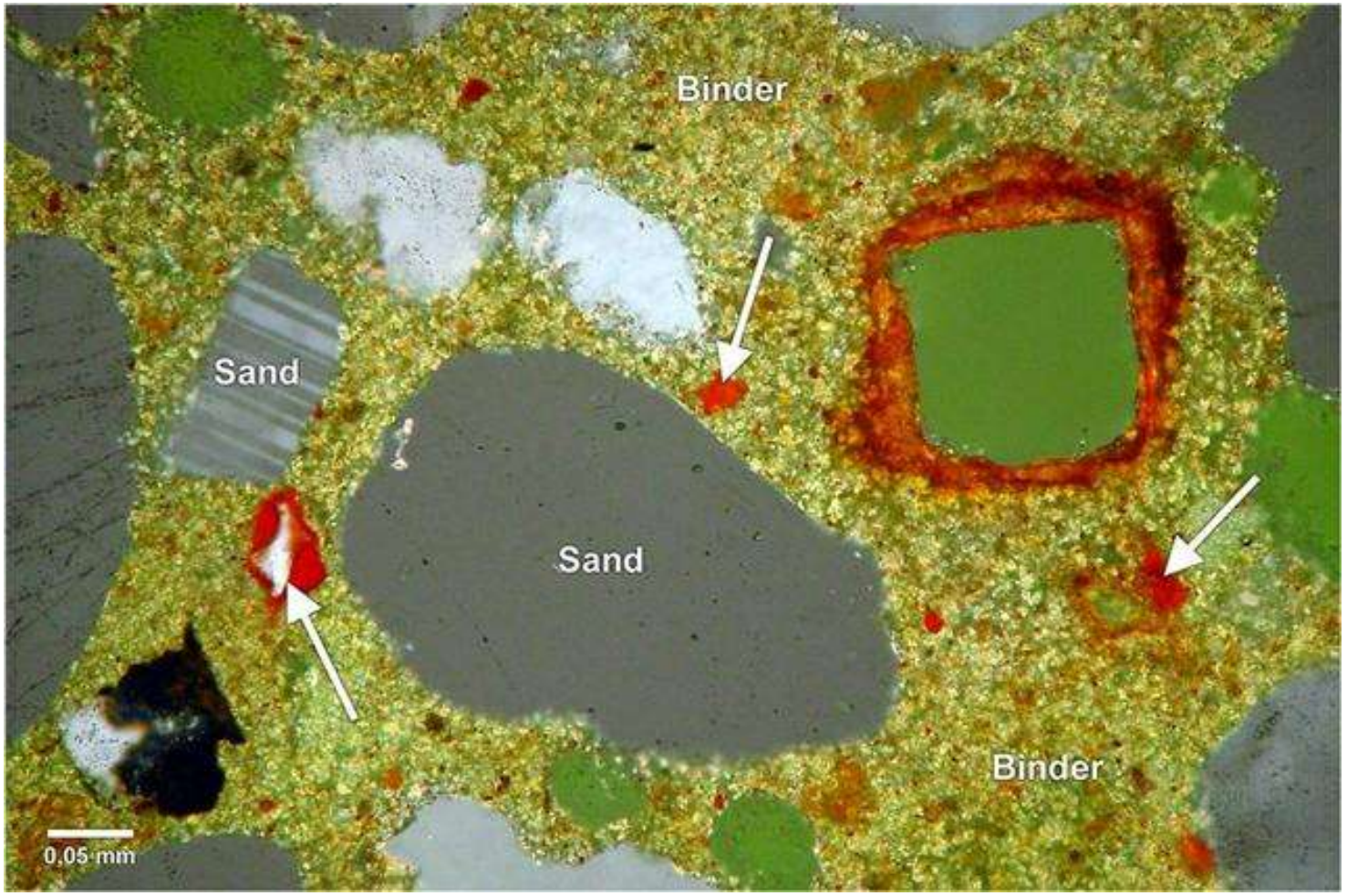

Brownish lumps of lime with impurities of primarily iron/clay-compounds (impure lime)



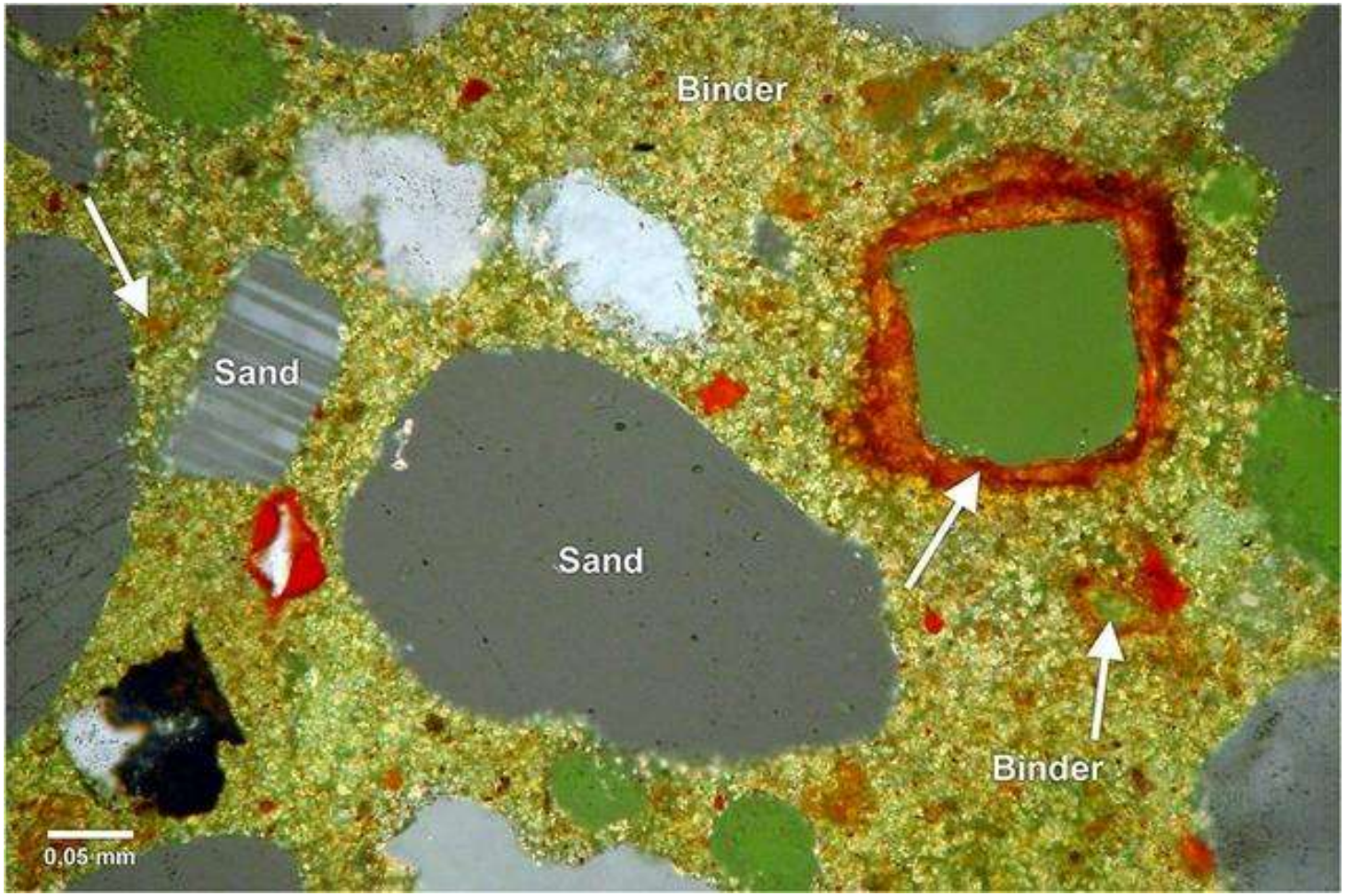

Clay/iron-compounds have transformed to ferrite ($C_4AF$)




White to greyish, often sub angular lumps of clay intermixed with small angular grains of quartz




Iron oxide (red coloured) – often in association with sand grains




Iron hydroxide , ochre (orange coloured ) – very often in association with an angular, sometimes cubic internal cavities

# Bornholm Cement – buildings


Domhuset, København: 1804-15.
New plaster with Bornholm Cement applied in the period1846-54

# Bornholm Cement – buildings

Vor Frue Kirke, København:  1811-29.
New plaster with Bornholm Cement applied in1849

# The end of Bornholm Cement

1910 prizes:

Bornholm Cement: 7,00 – 7,50 DKK per 100 kg
Portland Cement: 3,00 – 3,60 DKK per 100 kg

(Delivered in 100 kg and 50 kg bags)

(After Suenson 1911)

# The end of Bornholm Cement

The Cement plant Limensgade near Skelbro.  Circa 1920