# Some research themes in the field of geopolymers solved at the Dept. of Geology, Palacky University, Olomouc, Czech Republic

RNDr. Petr Sulovský, Ph.D.

and MSc. students – P. Niederle, T. Opletal, R. Srnský, P. Dleštík, V. Suchá, M. Šulcová

# Themes

- Utilization of geopolymers as stabilization / solidification matrices – for S/S treatment of fly ashes with anomalously high contents of toxic elements MSWI
- Geopolymer-based decorative stones -> assessment of compatibility of various rocks with metakaolin-based matrix
- Alkali-activated matrix for waste CRT glass bricks
- Alkali activation of calcined rocks and minerals other than kaolin

# GP´s as stabilization/solidification matrices

- Fly ashes highly enriched in hazardous elements: GP´s highly efficient >95% in fixing cations-forming metals Pb, Zn, Co, Ni, Cu thanks to $MeOH_2$ formation
- Problems arise with materials containing anions-forming ekements As, V, Mo (80-90%)
- Necessity of long-term testing (tank test)

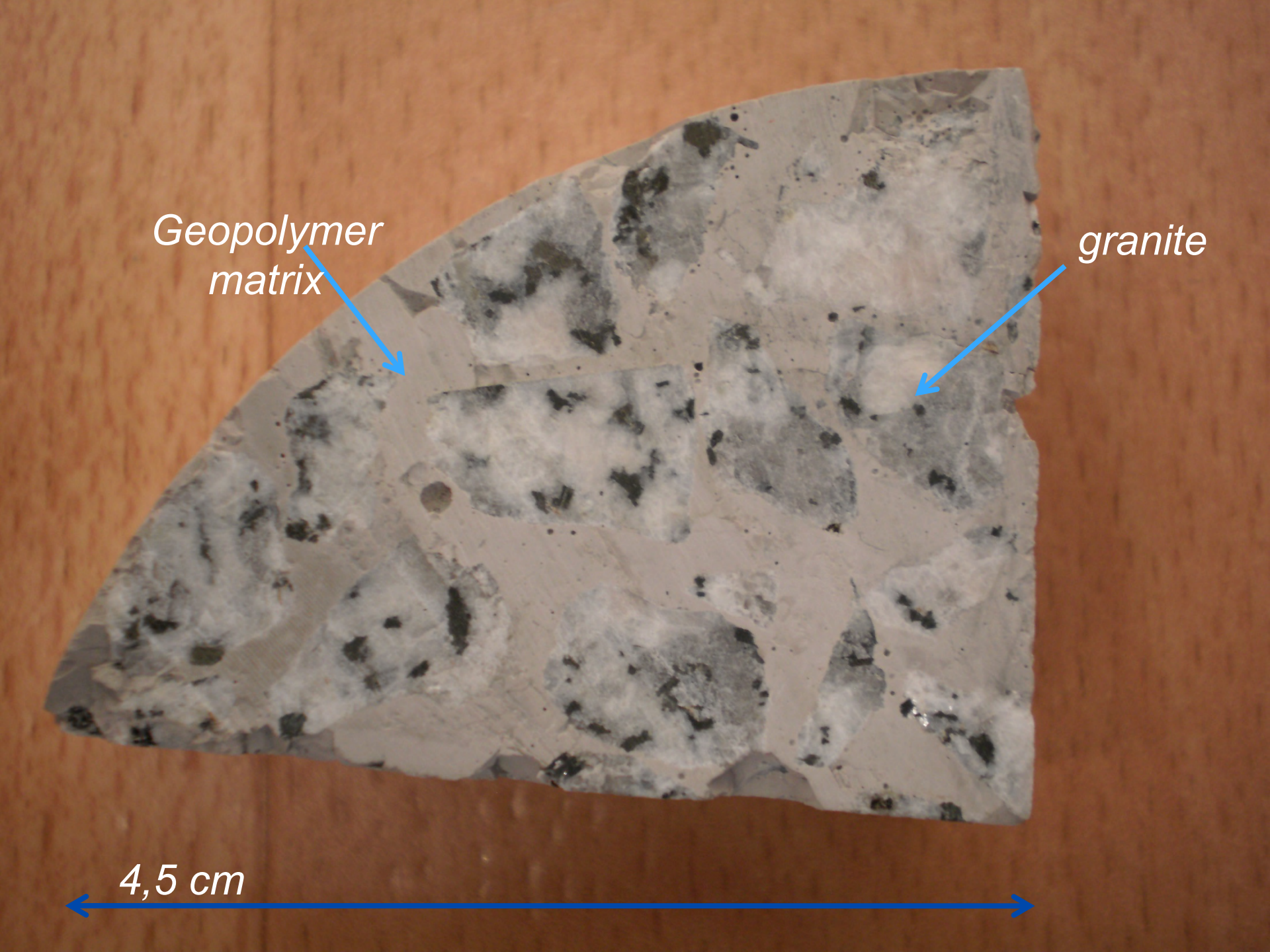
# Geopolymer-based decorative stones

- Assessment of compatibility of various rocks with metakaolin-based matrix: possible geopolymerization reaction at the rock fragment/GP matrix interface

# Geopolymer-based decorative stones

| sample | aggregate type | size fraction (mm) | metakaoline/ aggregate | compressive strength - MPa (28 days) |
|---|---|---|---|---|
| 1 | qtz sand | 1 - 2 mm | 1/3 | 90,1 Mpa |
| 2 | qtz sand | 1 - 2 mm | 1/4 | 66,1 Mpa |
| 3 | granite | 5 - 15 mm | 1/2,5 | 72,2 Mpa |
| 4 | marble | 7 - 14 mm | 1/3 | 59,0 Mpa |
| 5 | gravel (polymict) | 3 - 10 mm | 1/3 | 111,5 Mpa |

Assessment of compatibility of various rocks with metakaolin-based matrix: possible geopolymerization reaction at the rock fragment / GP matrix interface


Geopolymer
matrix
granite
4,5 cm

# Waste bottle glass

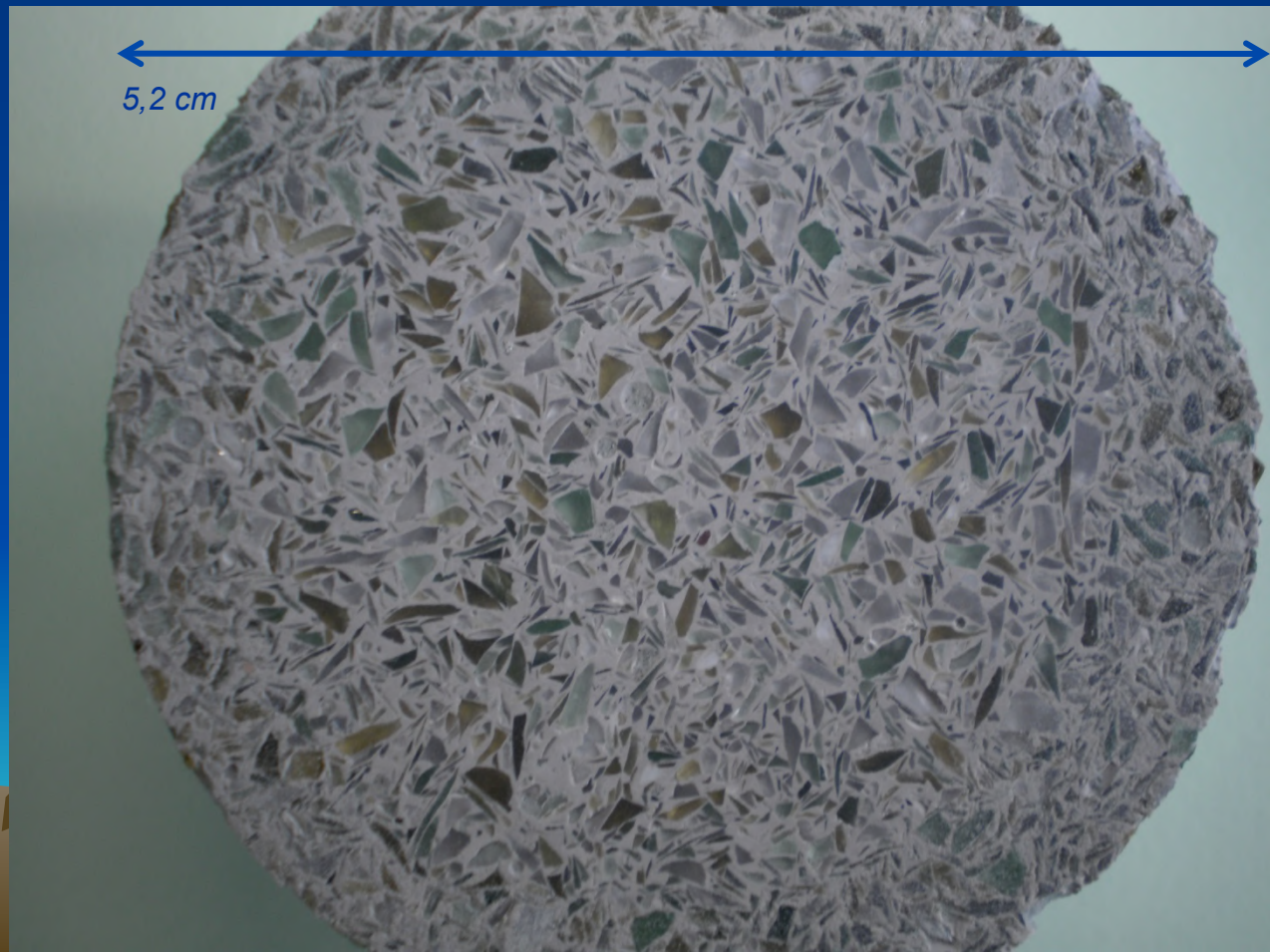
*activator: 40 g*

*metakaolíne: 50 g*

*Bottle glass : 150 g*

*Grain size: 0,5 – 2 mm*

*Strength: 94,25 Mpa*



# Waste CRT glass - hazardous waste

*activator: 80 g*
*metakaolín: 100 g*
*CRT glass: 300 g*
*frakce: < 2 - 10 mm*
*barvivo: 20 g akryl*
*c. strength:* ***170,9 MPa***

Geopolymer - based walls shielding ionizing radiation

7 cm

# MSWI residues (mix of 91%slag and 9% fly ash) – a hazardous waste

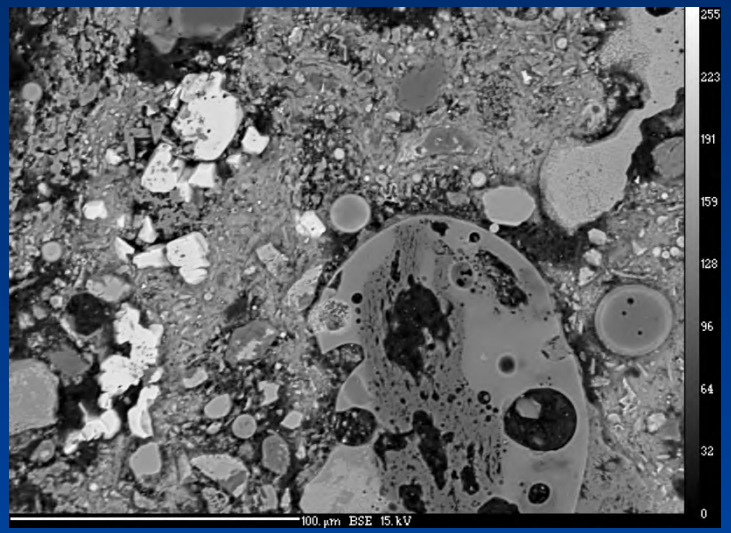
| Oxide | Wt.% |
|---|---|
| SiO2 | 49,9 |
| Al2O3 | 11 |
| Fe2O3 | 14,4 |
| CaO | 13,2 |
| MgO | 1,92 |
| SO3 | 0,93 |
| MnO | 0,15 |
| Na2O | 4,1 |
| K2O | 1,47 |
| TiO2 | 1,27 |
| P2O5 | 0,77 |
| Total | 99,2 |

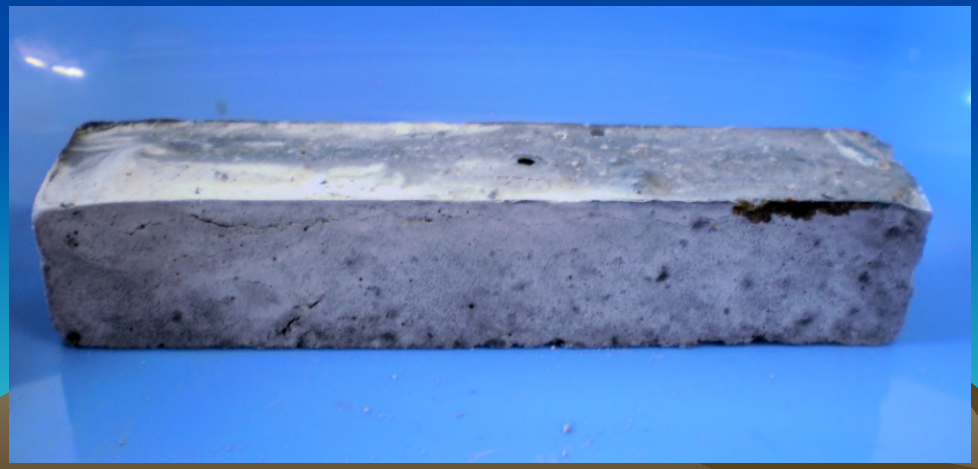
| | Content in dry matter (ppm) | Czech limit (ppm) |
|---|---|---|
| As | **226** | 10 |
| Ba | 2331 | |
| Cd | **154** | 1 |
| Cr | **399** | 200 |
| Cu | 1425 | |
| Hg | **3** | 1 |
| Mo | 20 | |
| Ni | **123** | 80 |
| Pb | **5776** | 100 |
| Sb | 990 | |
| Se | 16 | |
| V | 148 | 180 |
| Zn | 36401 | |

After washing (Cl removed)

# MSWI ash pretreatment (washing, calcination)

**MSWI ash without pretreatment – test prism**



$2\,Al + 6\,NaOH + nH_20 \rightarrow 3\,Na_2O\,.\,Al_20_3\,.\,nH_20 + \mathbf{3H_2}$

| Experiment no. | MSWI ash calcination temp. | Weight ratio A : M : P | 7 days compressive strength MPa |
|---|---|---|---|
| 1 | 310 °C | 3,1 : 3,8 : 3,1 | 32,5 MPa |
| 2 | 310 °C | 3,3 : 4,2 : 2,5 | 30,6 MPa |
| 3 | 400 °C | 2,9 : 3,6 : 3,6 | 35,1 MPa |
| 4 | 400 °C | 3,6 : 3,6 : 2,8 | 20,9 MPa |
| Reference concrete | | Ash:cement 1:1; w/c = 0,4 | 3,7 MPa |

A = waterglass, adjusted to silica module = 1,1; M = metakaolin
F = MSWI fly ash

# Alkali activation of calcined rocks

Search of suitable rocks – candidate substitutes of metakaolin

- Marienberg – phonolite
- Nižný Hrabovec - clinoptilolite tuff,
- Horní Bludovice – teshenite / by teshenite contactly metamorphosed sedimentary rock pelite
- Monomineral illite

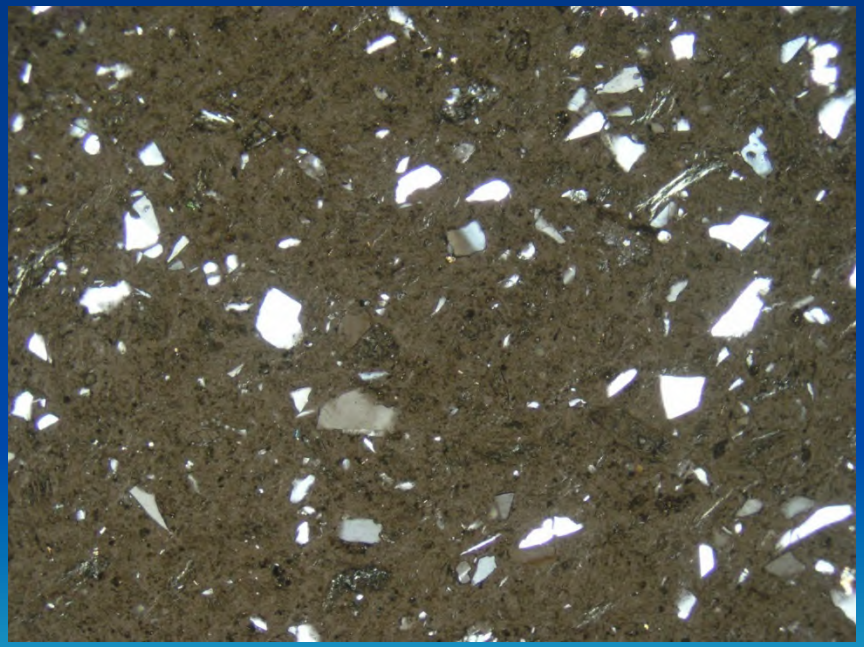
Foto: Pavel Niederle

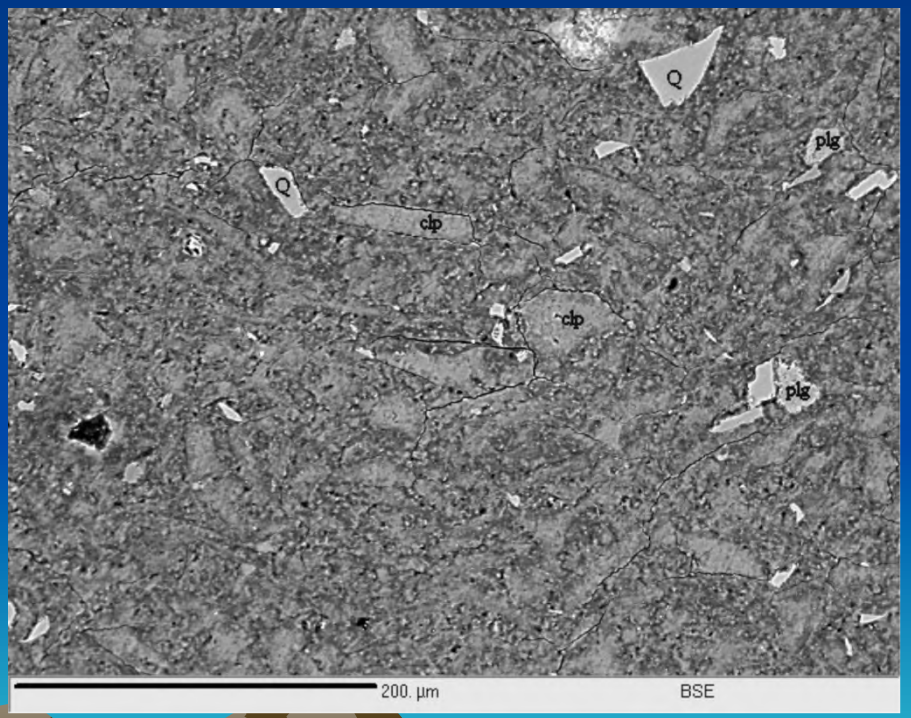
# Natrolite-rich phonolite Marienberg

**Augite, sanidine, natrolite, analcime, calcite**

# Zeolitic tuff (Nižný Hrabovec, Slovakia)

- Stable content (50-80 %) of K-Ca clinoptilolite associated with cristobalite and scarce plagioclase





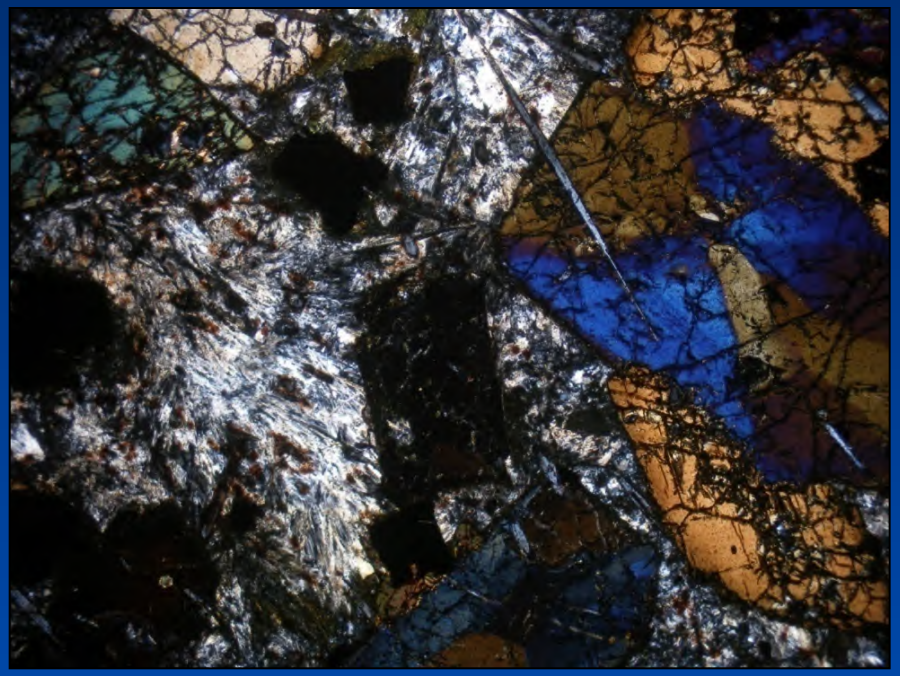

Optical microscopy – XPL

SEM -BSE

# Teschenite / contact metamorphic rock

Natrolite pigmented  with haematite, augit e with hourglass structure

# Teshenite



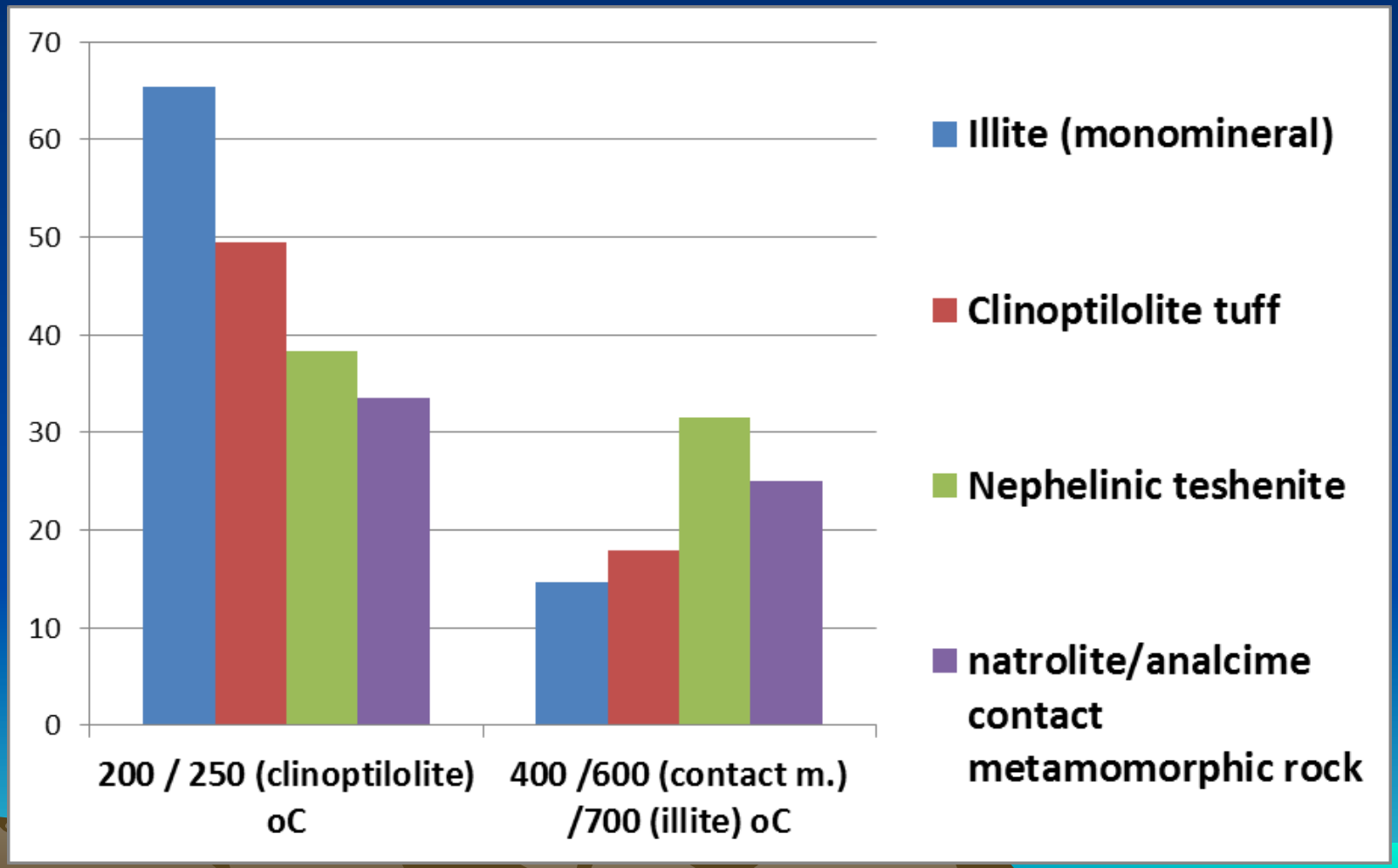
Composition of teschenite (XRD): natrolite, analcite, augite, pargasite, biotite, sanidine

# XRF analyses of rocks calcined at 200 ºC

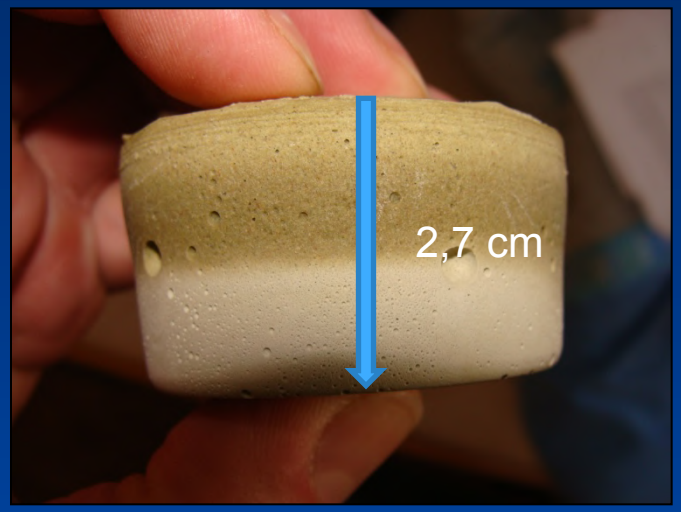
| Oxide | Teshenite | Cont. metam. | Phononolite | Clinoptilolite tuff |
|---|---|---|---|---|
| $SiO_2$ | 41,19 | 44,83 | 49,69 | 65,57 |
| $Al2O_3$ | 18,22 | 15,18 | 18,03 | 11,2 |
| $Fe2O_3$ | 10,13 | 5,47 | 2,34 | 1,44 |
| CaO | 8,05 | 7,63 | 1,81 | 2,99 |
| $Na_2O$ | 6,19 | 4,79 | 6,87 | 0,49 |
| MgO | 2,62 | 1,41 | 0,13 | 0,58 |
| $K_2O$ | 1,95 | 3,66 | 5,87 | 3,46 |
| $H_2O$ | 3,73 | 2,48 | 2,81 | 6,68 |
| $TiO_2$ | 1,92 | 0,67 | 0,43 | 0,18 |
| $P_2O_5$ | 1,51 | 0,08 | 0,08 | 0,03 |
| MnO | 0,2 | 0,08 | 0,08 | 0,02 |
| Si/Al | 1,918 | 2,506 | 2,338 | 4,967 |

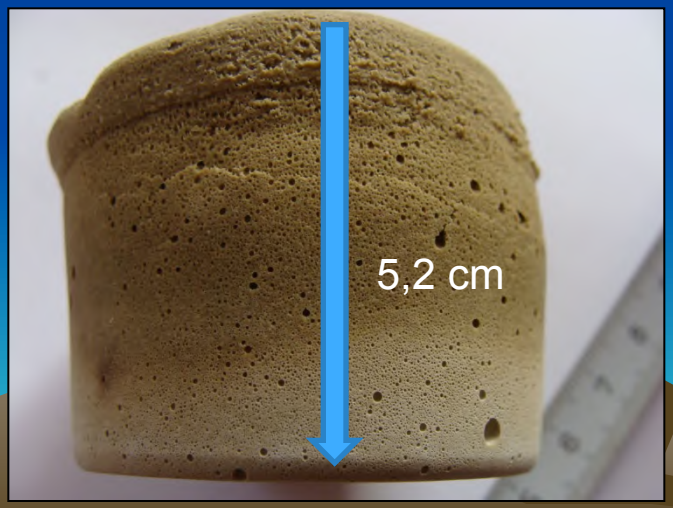
# Effect of calcination temperature

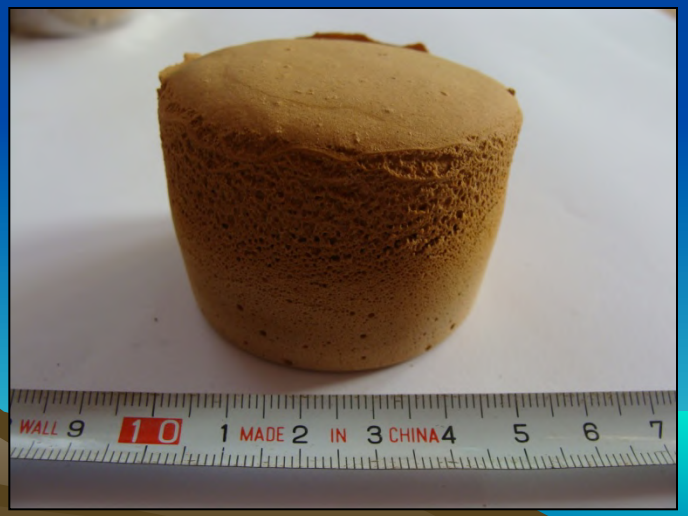
- calcination in superkanthal furnace – at  temeratures between 200 – 700 °



# The influence of calcination temperature on foaming




Thank you for your attention