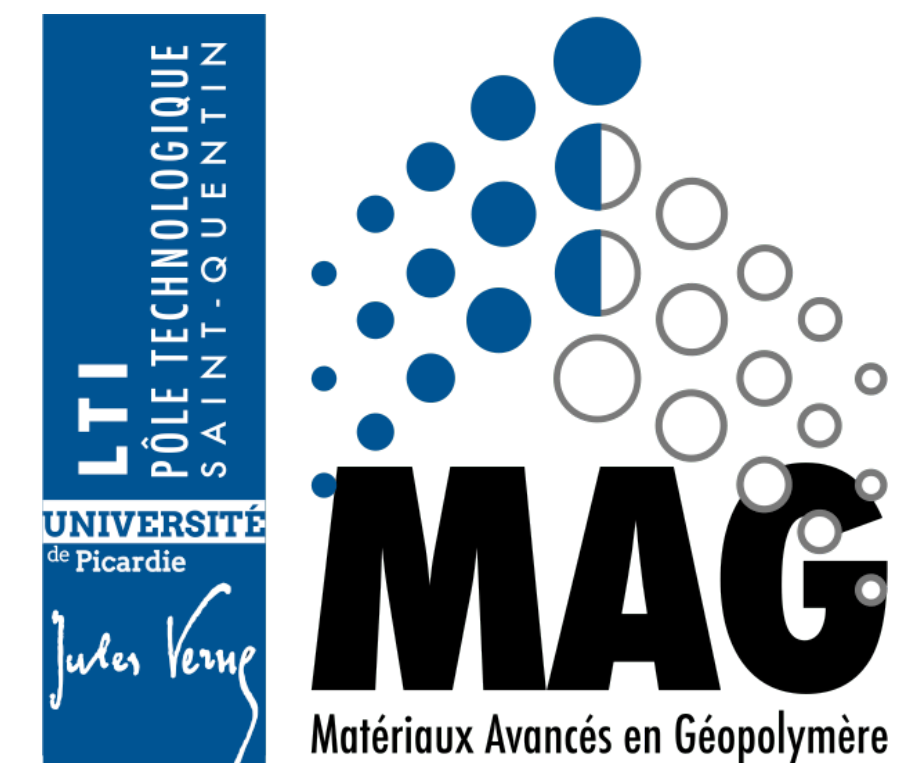
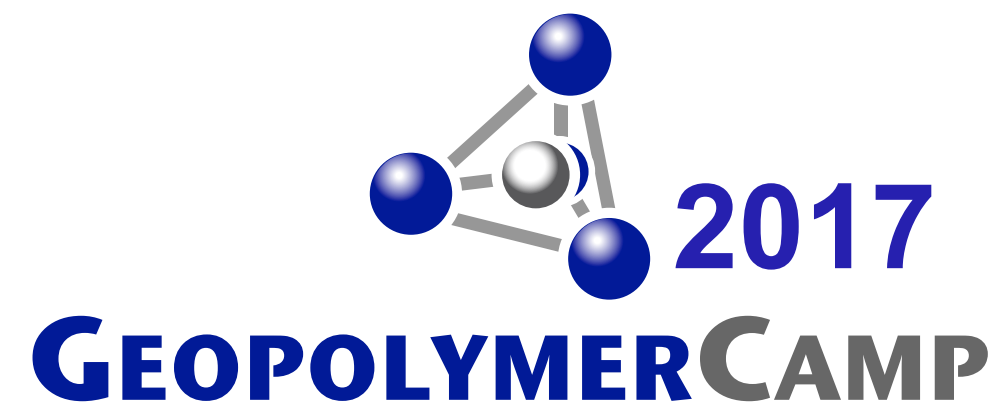


**9th GP-Camp**



**Saint-Quentin (France)**

**July 10-12, 2017**



*Joseph Davidovits*

Geopolymer Institute

[www.geopolymer.org](http://www.geopolymer.org)

# State of the Geopolymer R&D 2017



*Spring 2017*

[www.geopolymer.org](http://www.geopolymer.org)

# *Geopolymer Webinar Spring 2017*

## *Registered participants,*





Available for free download at [www.geopolymer.org](http://www.geopolymer.org)

## Technical papers

24 pdf

## Archaeological papers

9 pdf

### Category: Technical papers

Papers dealing with geopolymer science and applications



#### # 24 False CO2 Values Published in Scientific Papers

7 Dec 2015

Technical paper #24 False Values on CO2 Emission for Geopolymer Cement/Concrete Published in Scientific...



#### #22 GEOASH: ambient temp. hardening of fly ash-based geopolymer cements

16 Jul 2014



#### #23 Technical Paper on Geopolymer Aircraft Pavement

27 Oct 2015

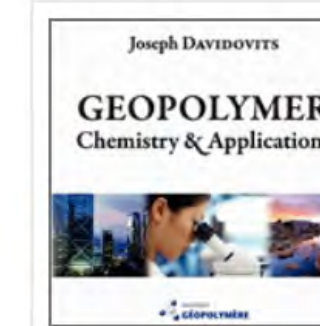
Technical paper # 23 GP-AIRPORT in our Library Last year (October 14, 2014), our News was titled 70,000 tonnes...



#### #21 Geopolymer cement review 2013

6 Feb 2013

A review on Geopolymer cement, as of January



Get the new edition of the reference book **Geopolymer Chemistry & Applications** at a special price

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- News
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  - Civilization
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  - Geopolymer Camp
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- Books / Tutorial
- Library / Papers
  - Archaeological papers
  - Technical papers
  - Video
- FAQ

### Latest articles

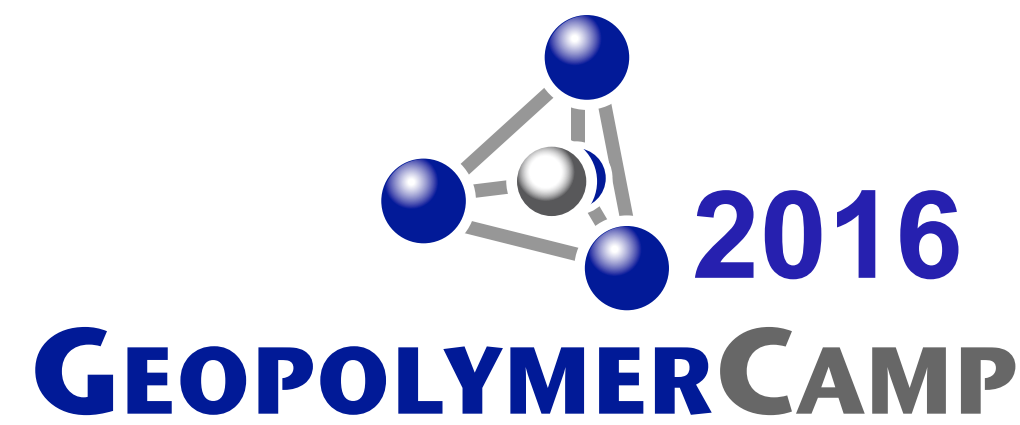


**GPCamp 2016**

13 Jul 2016



Available for free download at [www.geopolymer.org](http://www.geopolymer.org)



8 Videos: State of the Geopolymer R&D

11 Videos: Special Keynotes

12 Videos: Lectures Spring 2014 and Spring 2016



Joseph Davidovits

Why Alkali Activated Materials  
are **NOT** Geopolymers ?

Excerpt from the keynote:  
State of the Geopolymer R&D 2014

© July 2014 - Geopolymer Institute - Geopolymer Camp

3 Videos: Why Alkali Activated Materials  
are **NOT** Geopolymers?

# Why Alkali-Activated Materials (AAM) are not Geopolymers ?



Joseph Davidovits

Why Alkali Activated Materials  
are **NOT** Geopolymers ?

Excerpt from the keynote:  
State of the Geopolymer R&D 2014

© July 2014 - Geopolymer Institute - Geopolymer Camp

**Part 1:** Aug. 2014

Excerpt Geopolymer R&D 2014

*GP-Institute > 14,600    YouTube > 5,800*

**Part 2:** Aug. 2015

Excerpt Geopolymer R&D 2015

*Part 2: Clarifying statement and historicity.*

*GP-Institute > 5,900    YouTube > 1,800*

**Part 3:** Aug. 2016

Excerpt Geopolymer R&D 2016

*Part 3: What scientists are now writing  
on this issue.*

*GP-Institute > 2,620    YouTube > 650*



# From Theory to Global Industrialization



Geopolymer binder / resin

paint / coating / grout

Geopolymer foam

Geopolymer cement

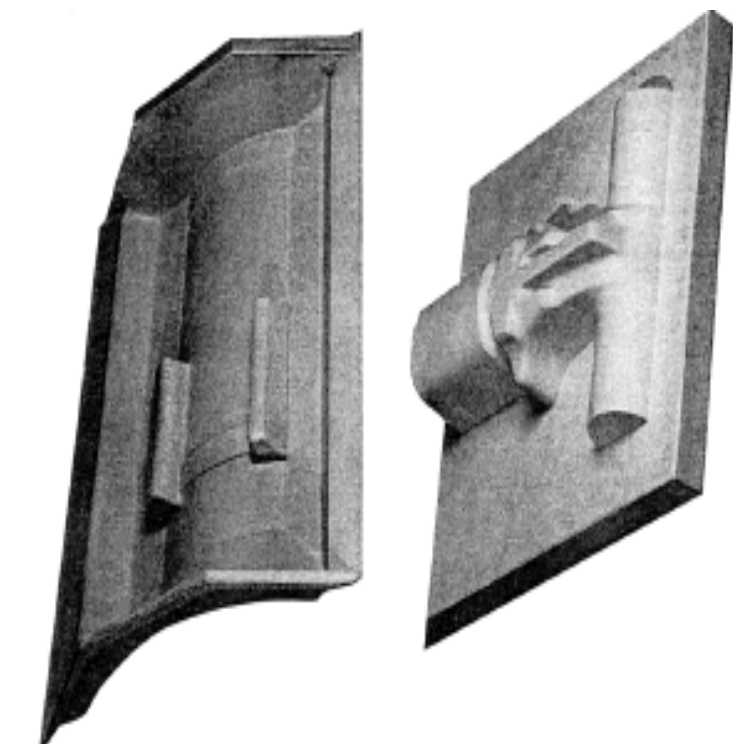
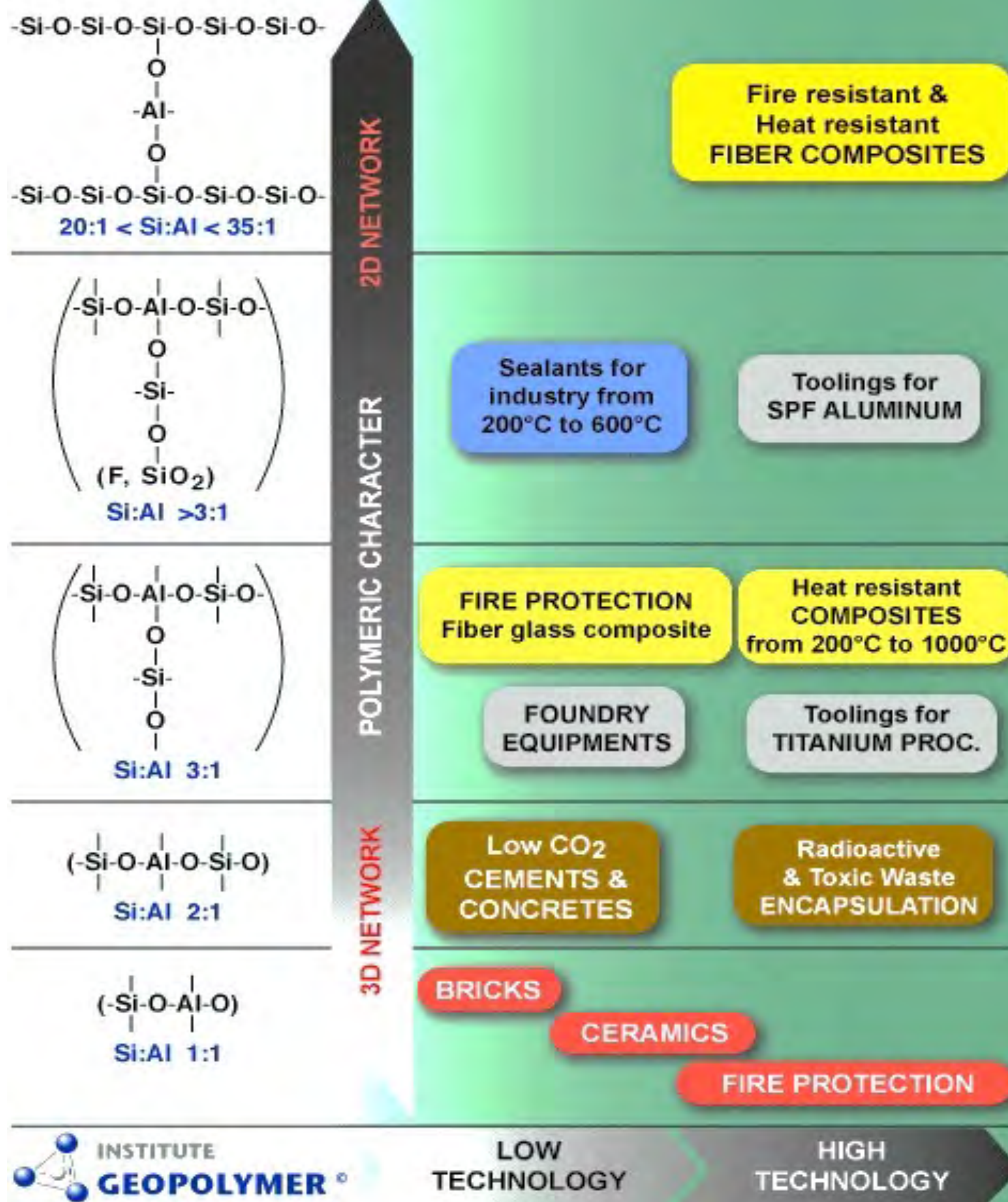
Geopolymer concrete

Geopolymer carbon/composite

Geopolymer ceramics



# MK-750 / SiO<sub>2</sub> based geopolymers











**Plastics are  
dangerous !!**

**Are organic  
polymers heat  
resistant ??**



- No! NATURE states :
- Only MINERALS provide fire and heat resistance
- Target: Inorganic polymers

# Geopolymers are

Polymers,

processed like organic polymers

Yet,

GEO-polymers

Fire and heat resistant

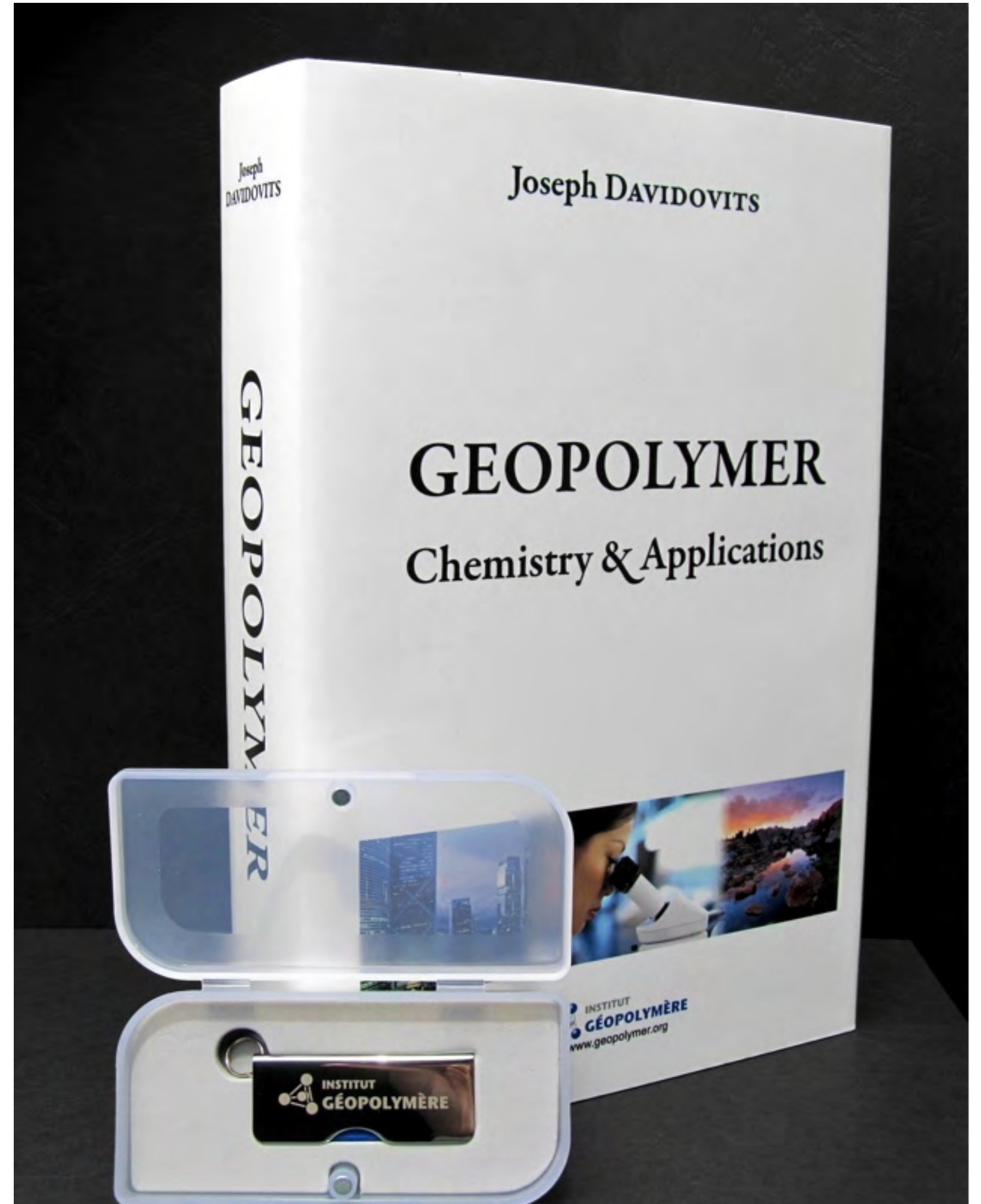
# Chapter 22

Fire and Heat resistant

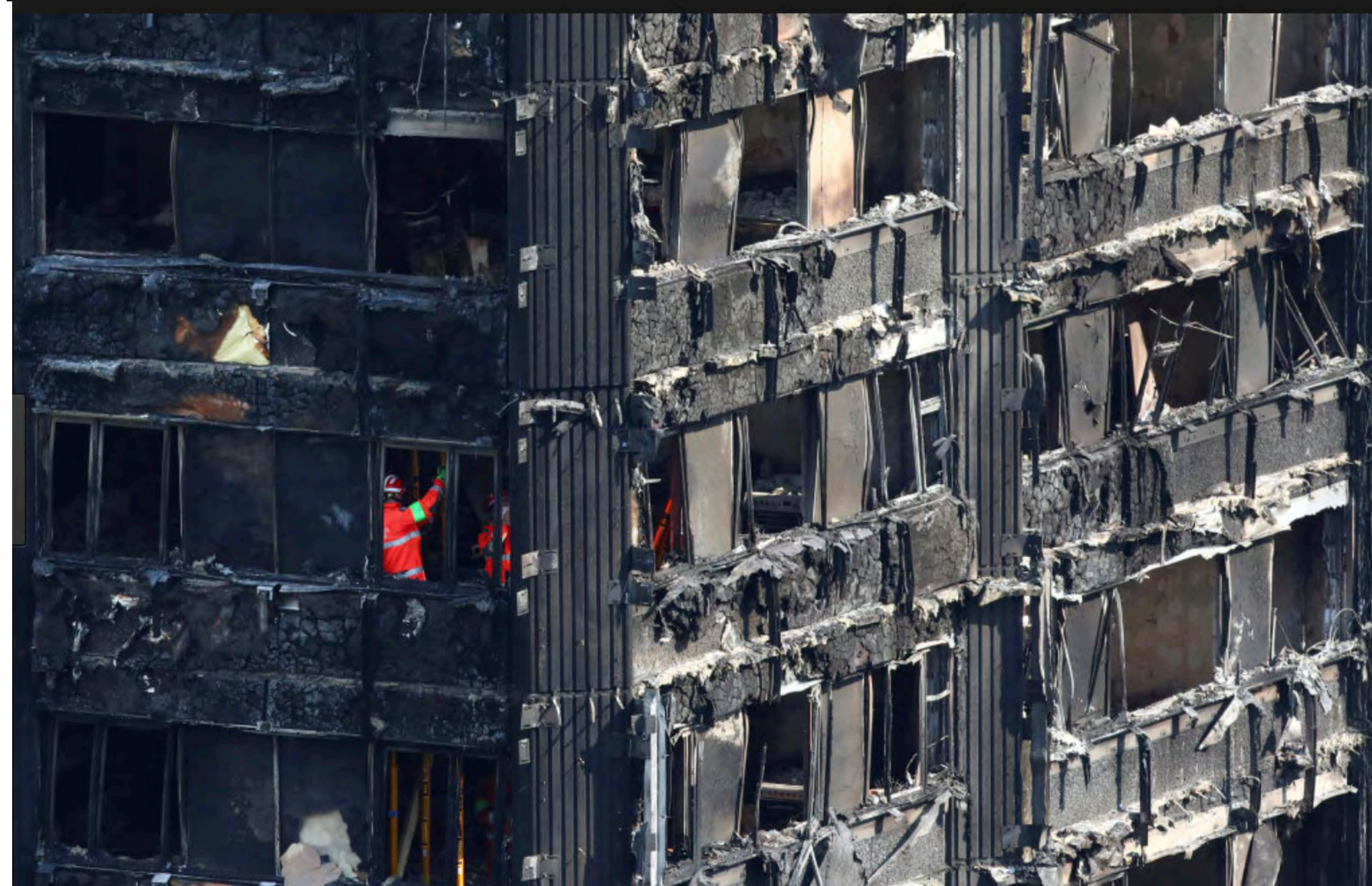
Geopolymer Foam

Trolit<sup>®</sup> 1987

Too expensive !!







June 14, 2017  
30 years later  
London Grenfell Tower

**80 people died ! Is it too expensive ?**



# BASF Germany

PCI-GEOFUG® , geopolymer  
grout and binder

[www.pci-augsburg.de](http://www.pci-augsburg.de)





# Milliken Infrastructures USA

Geopolymer mortar systems  
and grouts for use in  
rehabilitation

[infrastructure.milliken.com](http://infrastructure.milliken.com)





ASK  
Chemicals  
(Ashland)  
Germany

INOTEC Inorganic Binder  
System, geopolymer binder  
for foundries

[www.ask-chemicals.com](http://www.ask-chemicals.com)



**BMW  
SUPPLIER  
INNOVATION  
AWARD  
2014**





# Wagners Australia

Earth Friendly Concrete: fly  
ash / slag geopolymer  
concrete for infrastructures

[www.wagner.com.au](http://www.wagner.com.au)

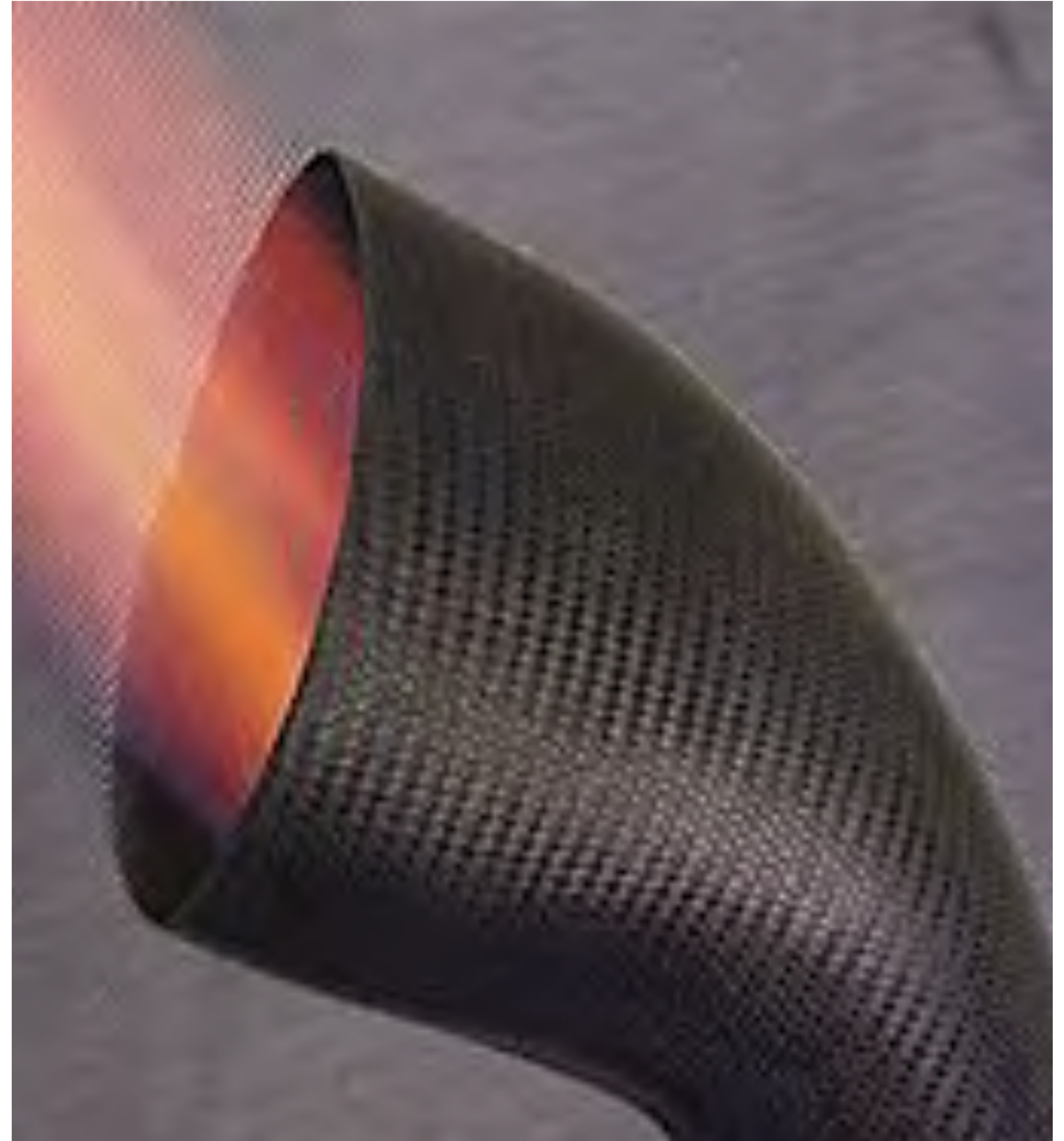




# Pyromeral Systems France

High-tech high-temperature  
structural geopolymer  
composite materials for  
automotive, aircraft industries

[www.pyromeral.com](http://www.pyromeral.com)





# Éire Composites Ireland

MechTool®: Heated  
geopolymer composite  
tooling for manufacture of  
large composites structures  
(aerospace, wind mill  
energy)

[www.eirecomposites.com](http://www.eirecomposites.com)

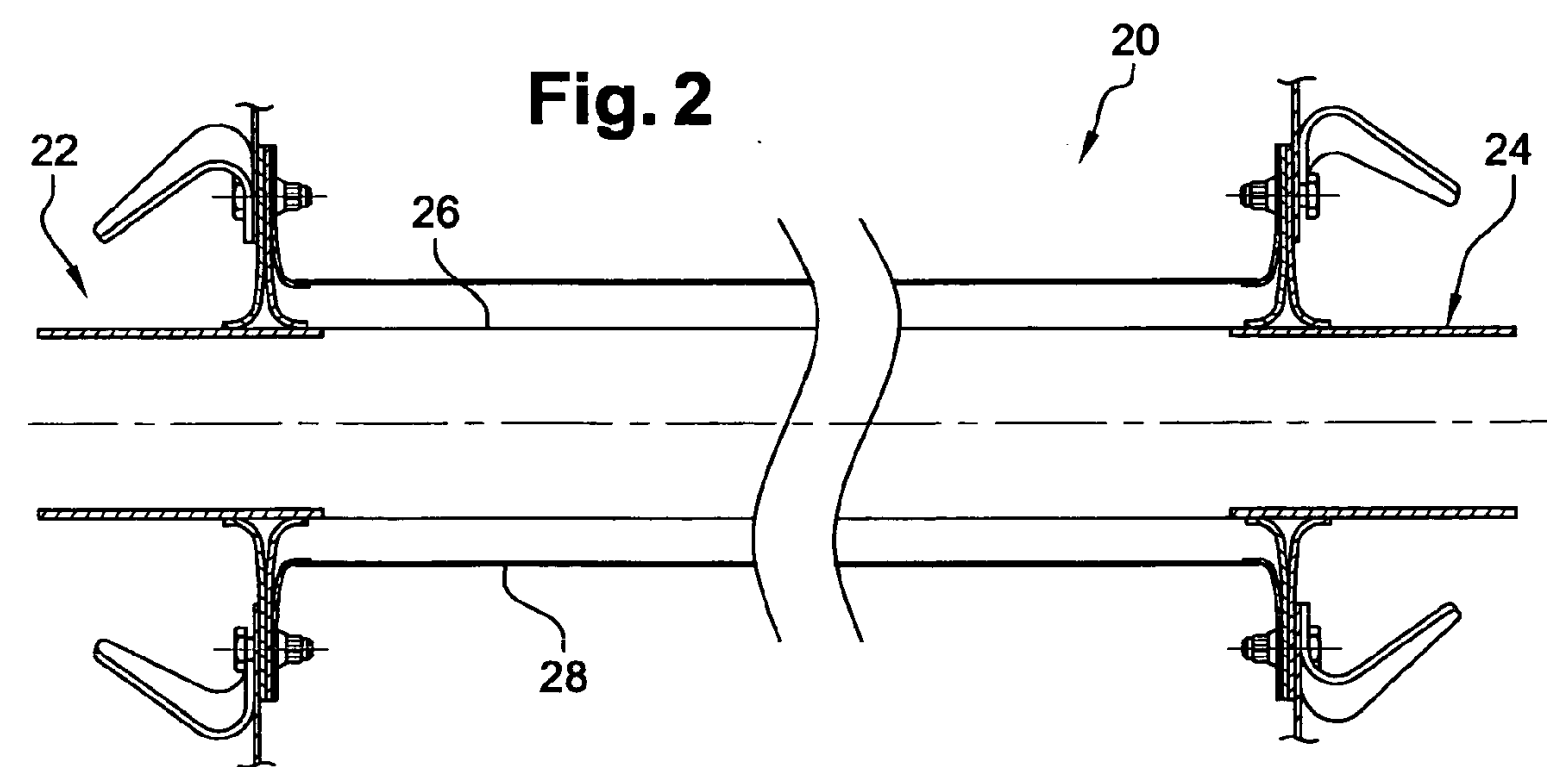




Airbus  
France

Aircraft conduit in  
geopolymer carbon  
composite

Patent: US 20090197031 A1  
FR2007051747





# Schlumberger France

Patent: WO/2008/017414  
Pumpable geopolymer  
formulation for oilfield  
application





# Rockwool Australia

Geopolymer rockwool  
brickettes used to recycle  
unused fibers





Commissariat  
à l'Énergie  
Atomique  
France

Patent WO/2009/050196  
Method of preparing a  
controlled porosity  
geopolymer for catalysis and  
filtration

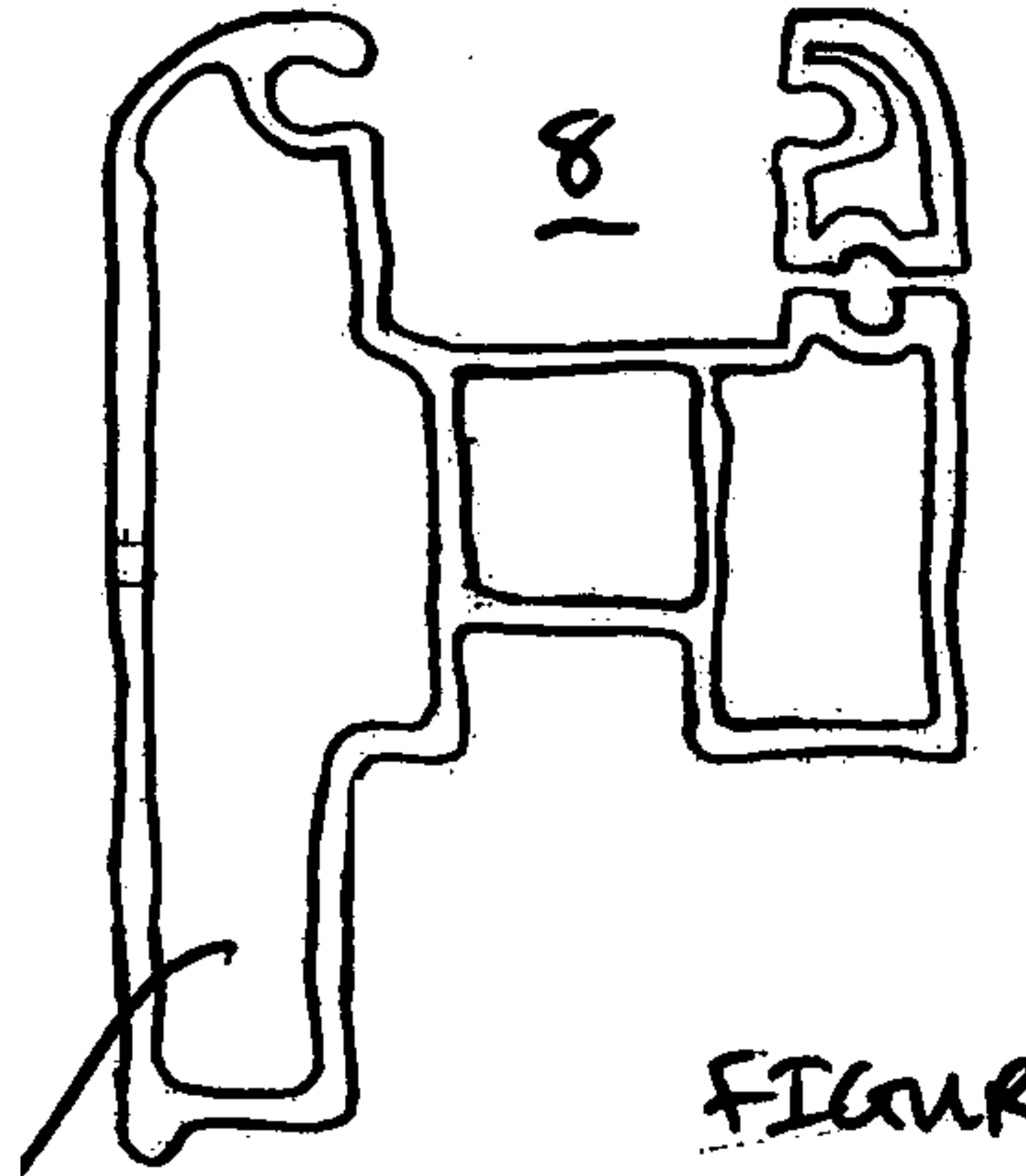




# Alsitek Limited UK

Patent WO/2009/050472  
Extruded geopolymer frame  
profiles for windows or doors

[www.alsitek.co.uk](http://www.alsitek.co.uk)

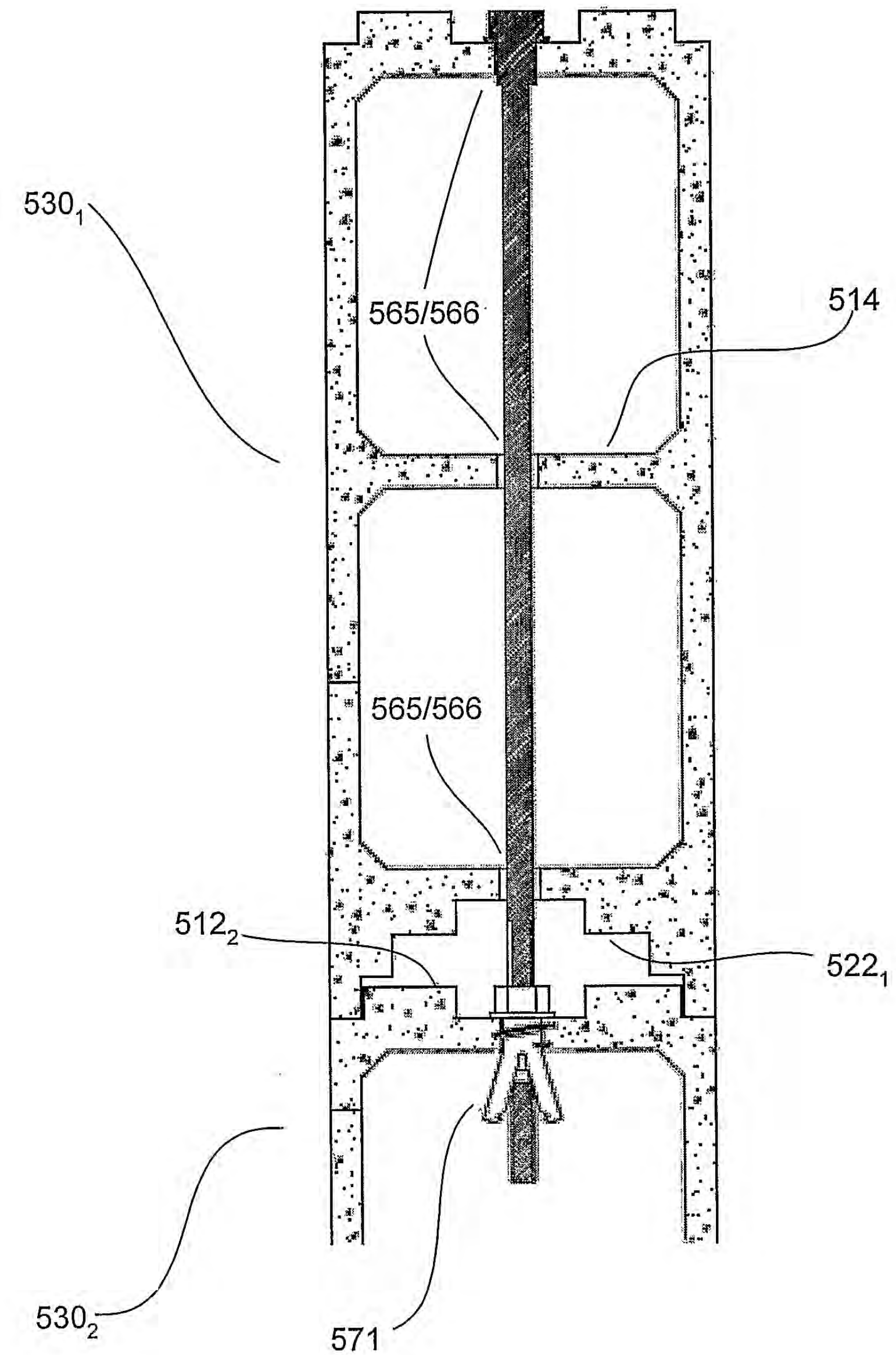




# Matakii Panels Singapore

Patent WO/2009/025620  
Precast geopolymer panels

[www.matakiipanels.com](http://www.matakiipanels.com)

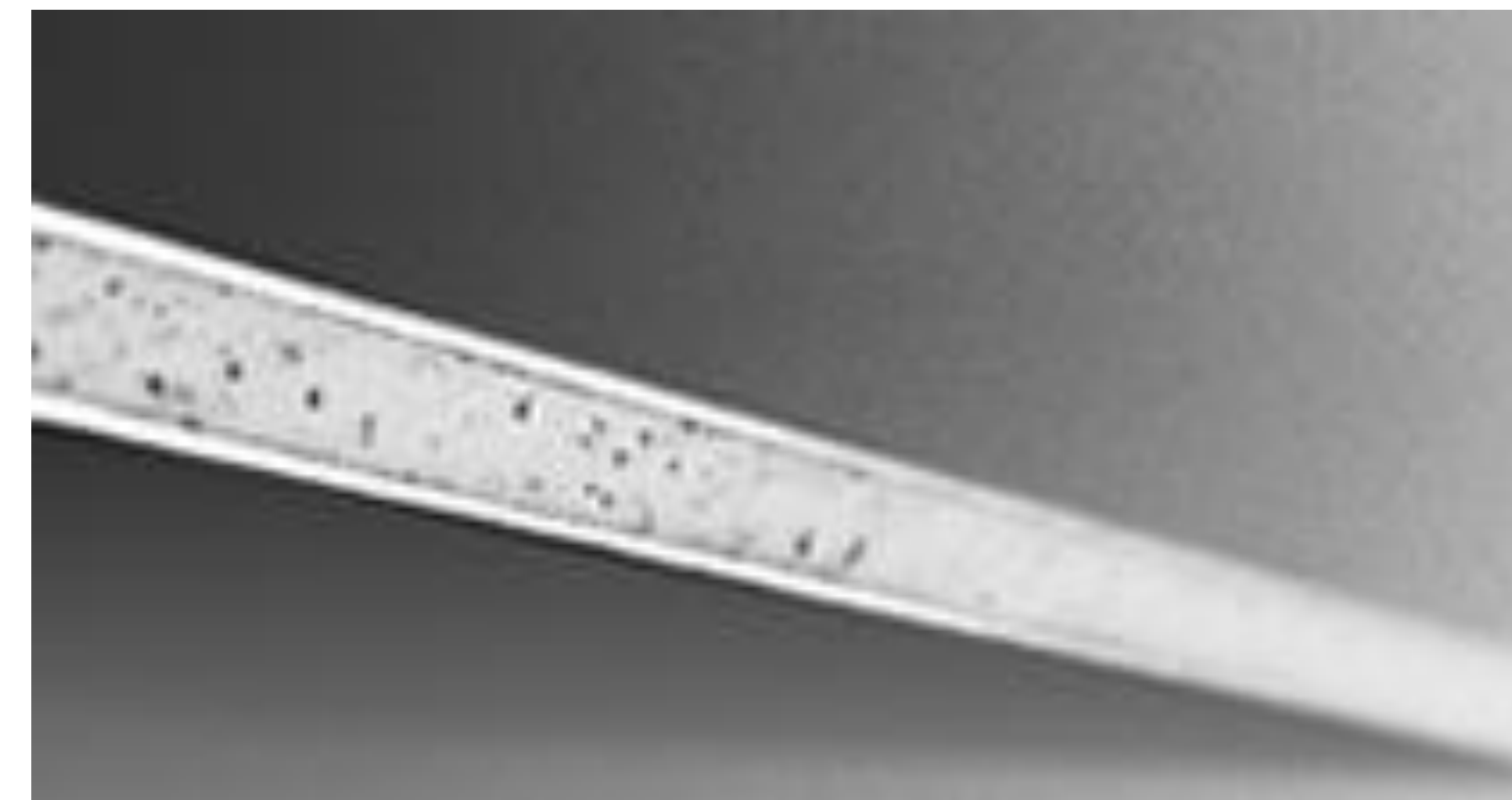




# NU-Core A2FR China

Geopolymer Fireproof  
Composite Panels

[www.nu-core.com.cn](http://www.nu-core.com.cn)

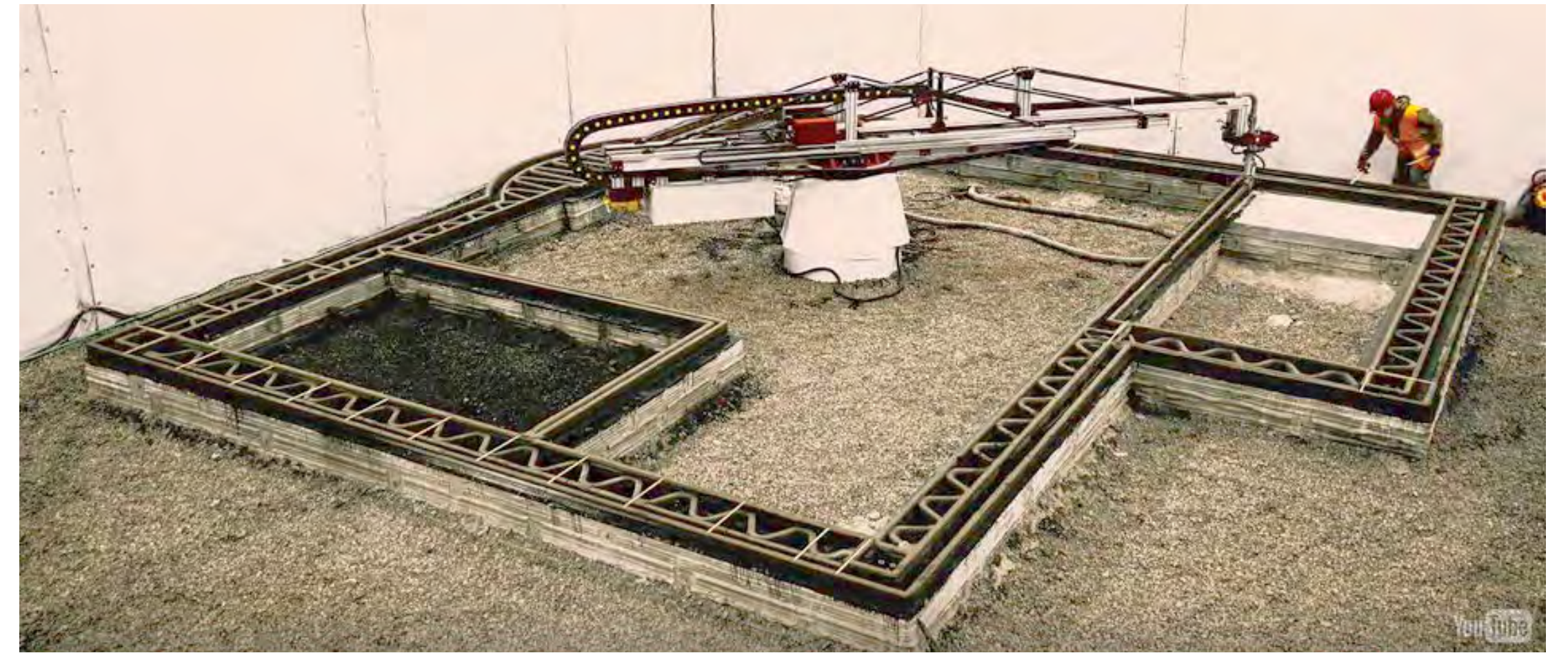




# Renca Russia

3D Printer for buildings.  
Development with Apis-Cor  
of a 3D printer with a fast  
setting geopolymer concrete

[www.renca.com](http://www.renca.com)

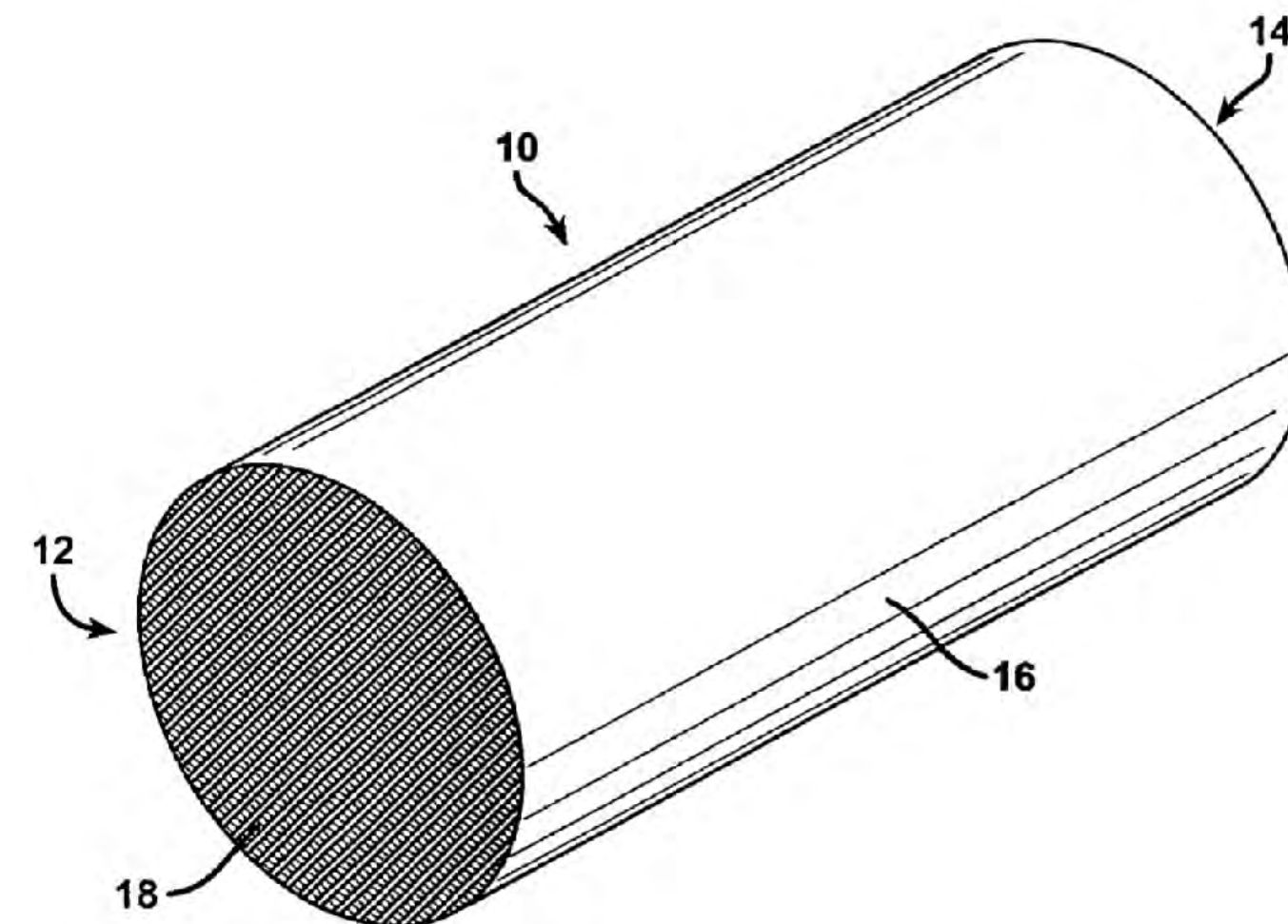




# Corning USA

Patent US 7745363  
Geopolymer ceramic  
composites for high  
temperature

[www.corning.com](http://www.corning.com)





# Dow Chemical USA

Patent WO/2010/138351  
Geopolymer coating for  
organic polymer substrates

[www.dow.com](http://www.dow.com)





# Orexo AB Sweden

Patent WO/2010/128300  
Composition for sustained  
drug delivery comprising  
geopolymeric binder

[www.orexo.com](http://www.orexo.com)





# INOMAT Germany

Ino-Flamm®  
Patent WO/2011/029444  
Fire resistant geopolymer  
paint

[www.inomat.de](http://www.inomat.de)





# Sinotec Germany

Sinocoat®

Very resistant and acid-proof  
rigid anti-corrosive  
geopolymer coating for the  
protection of surfaces on  
metallic and mineral basis

[www.sinnotec.eu](http://www.sinnotec.eu)



# GeoPol Czech Rep.

Geopolymer sand binder for  
cores in foundries

[www.geopol-info.com](http://www.geopol-info.com)



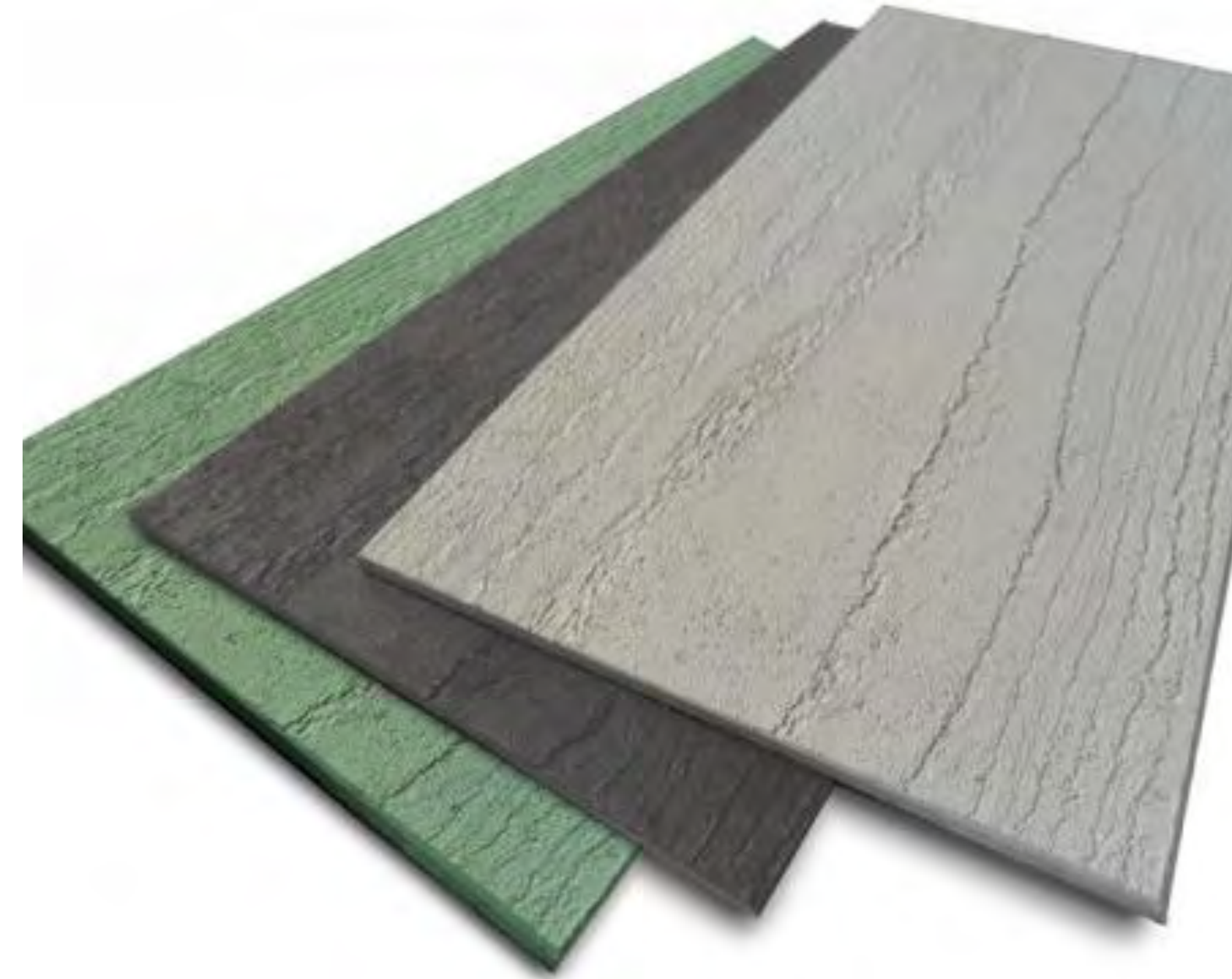


# Nova Lignum Netherlands

Ceranex™  
Geopolymer composite  
sidings and façade  
claddings

[www.novalignum.nl](http://www.novalignum.nl)

 ceranex



# NanoVoltaics Inc. USA

Nanoporous geopolymer  
(npGEO™) composites for  
use in water treatment as an  
adsorbent for the removal of  
arsenic.

[www.nanovoltaics.com](http://www.nanovoltaics.com)





# Allied Foam Tech Corp. USA

GeoFoam: geopolymer foam  
cement, for lightweight and  
fireproof applications

[www.alliedfoamtech.com](http://www.alliedfoamtech.com)



# Vodnis Klo Czech Rep.

Desil AI™  
Geopolymer binder system  
for foundries

[www.vodnisklo.cz](http://www.vodnisklo.cz)





# PolyRap Canada

Econcrete: geopolymer  
concrete made out of mine  
tailings

[www.polyrap.net](http://www.polyrap.net)



**RECYLED GLASS AS AN  
ADMIX TO POLYMER  
AND GEOPOLYMER**

---



# Argio Belgium

ArgioBricks: LTGS bricks  
(low temperature geopolymer  
setting)

[www.argio.com](http://www.argio.com)



Brabant flamand, Meise.

Architecte : Maarten Martens

+ 25 logements, 2.500 m<sup>2</sup> de maçonnerie Argio apparentes.



# Reinforced Concrete Pipes Australia

eCP: geopolymer concrete  
pipes

[www.rcpa.com.au](http://www.rcpa.com.au)





# Watershed Materials USA

Geopolymer blocks made  
out of clay, geology, rice  
husk, lime and slag

[watershedmaterials.com](http://watershedmaterials.com)





# Bowers Industrial USA

A200 to A600 geopolymer  
concrete (quartzite fillers) for  
acid resistant applications

[www.bowersindustrial.com](http://www.bowersindustrial.com)



# Aquaminerals Finlands

Solutions for water  
purification with patented  
geopolymer nitrogen removal  
adsorbents

[www.aquaminerals.fi](http://www.aquaminerals.fi)





# Amec Foster Wheeler United Kingdom

SIAL® matrix, a specialised  
geopolymer technique for  
encapsulating various  
radioactive waste streams.

[www.amecfw.com](http://www.amecfw.com)





# Wincret Brazil

Decorative architectural  
geopolymer binder panels  
for inside and outside

[www.winblok.com.br](http://www.winblok.com.br)





# Néoterre France

Geobiology applications

[www.neoterre.com](http://www.neoterre.com)



# Geopolymer research 1988

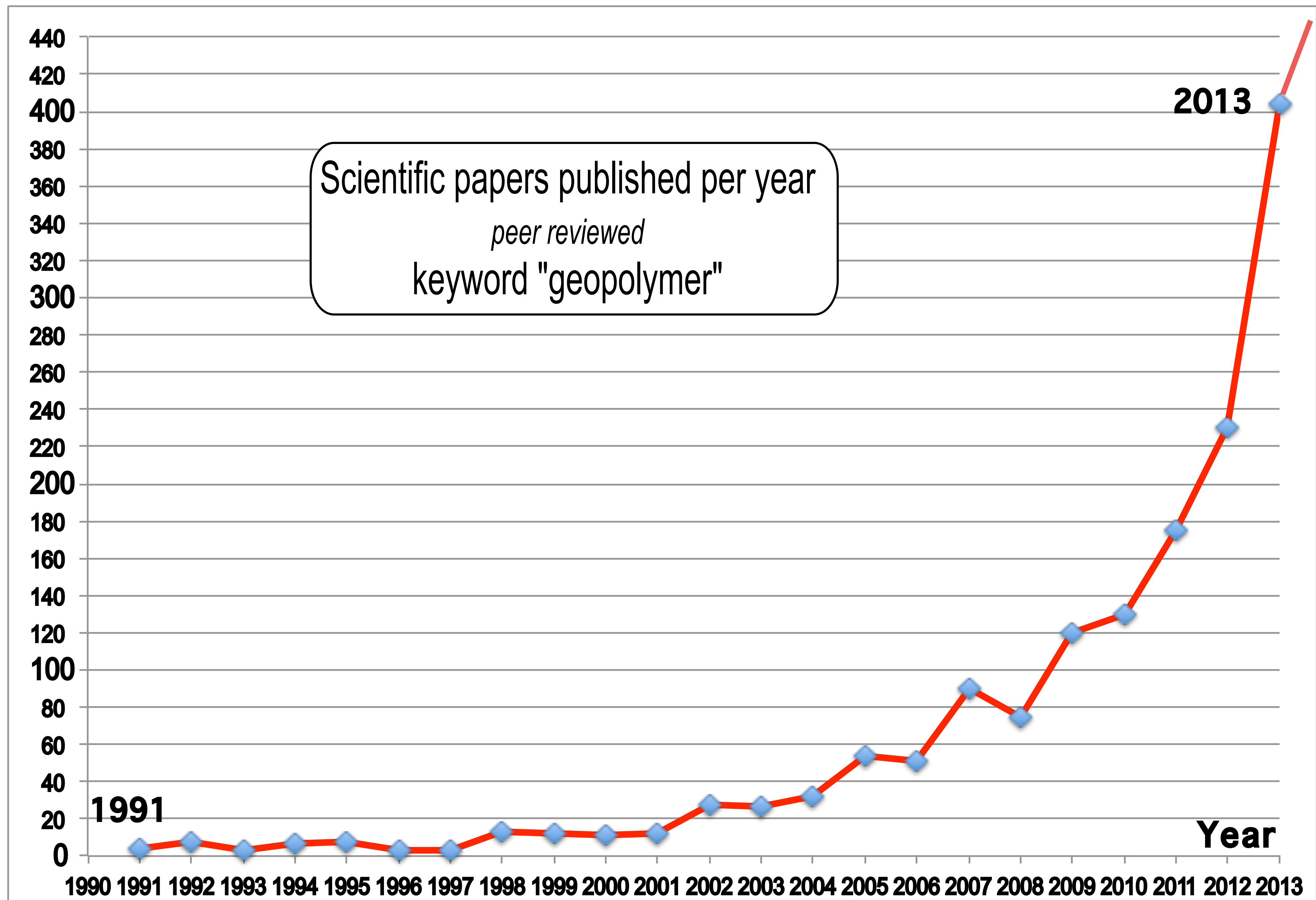
1st Geopolymer conference






# Geopolymer research 2016







# Kuala Lumpur, October 12-13, 2017



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Conference Information ICGCGC 2017 : 19th International Conference on Geopolymer Cement and Geopolymer Concrete

WASET fake conferences on Geopolymers ??

Environ 82 700 résultats (0,65 secondes)

**icgcfg 2017 - World Academy of Science, Engineering and Technology**  
<https://www.waset.org/conference/2017/10/kuala-lumpur/ICGCGC> Traduire cette page  
 The ICGCGC 2017: 19th International Conference on Geopolymer Cement and ... ICGCGC 2017 has teamed up with the Special Journal Issue on Geopolymer Cement and ... Please ensure your submission meets WASET's strict guidelines for ...

**ICGT Prague 2017: 19th International Conference on Geopolymer ...**  
<https://www.waset.org/conference/2017/03/prague/ICGT> Traduire cette page  
 23 mars 2017 - The ICGT 2017: 19th International Conference on Geopolymer Technology aims to bring together leading academic scientists, researchers and ...

**Call for Papers - World Academy of Science, Engineering and ...**  
<https://waset.org/conference/2017/10/kuala.../call-for-papers> Traduire cette page  
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**ICGCGC Home - World Academy of Science, Engineering and ...**  
<https://waset.org/conference/2017/10/kuala-lumpur/.../home> Traduire cette page  
 ICGCGC 2017 : 19th International Conference on Geopolymer Cement and Geopolymer Concrete ... Abstracts : [waset.org/abstracts/urban-and-civil-engineering](https://waset.org/abstracts/urban-and-civil-engineering).

**ICCCC Istanbul 2017: 19th International Conference on Cement and ...**  
<https://www.waset.org/conference/2017/10/istanbul/ICCCC/home> Traduire cette page  
 ICCCC 2017 : 19th International Conference on Cement and Concrete Chemistry ... Abstracts : [waset.org/abstracts/chemical-and-molecular-engineering](https://waset.org/abstracts/chemical-and-molecular-engineering) ... Geo- polymer, Low Carbon Cement, Low Carbon and Green Development, Standard ...

**ICGC Saint Petersburg 2017: 19th International Conference on ...**  
<https://www.waset.org/conference/2017/09/saint.../call-for-papers> Traduire cette page  
 The ICGC 2017 : 19th International Conference on Geopolymer Concrete is the premier interdisciplinary platform for the presentation of new advances and ...



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# Lisbon, April 16-17, 2017

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## ICGC 2017 : 19th International Conference on Geopolymers and Ceramics

Lisbon, Portugal  
April 16 - 17, 2017



# Presented papers

## SESSION 1

Chair : Victoria Goodall

- 1 Oral **Development of Automatic Farm Manure Spreading Machine for Orchards**  
Barış Ozluoymak, Emin Guzel, Ahmet Ince  
Cukurova University Turkey
- 2 Oral **Comparison of Methods for the Detection of Biofilm Formation in Yeast and Lactic Acid Bacteria Species Isolated from Dairy Products**  
Goksen Arik, Mihriban Korukluoglu  
Uludag University Turkey
- 3 Oral **Assessment of Germination Loss Due to Dusky Cotton Bug (*Oxycarenus laetus*) in Relation to Cotton Boll Stage and Bug Intensity**  
Ali Hassan, Mian Muhammad Awais, Muhammad Rafique Shahid, Farazia Hassan, Shumaila Rasool  
University of Agriculture Faisalabad Pakistan
- 4 Oral **Exposure of Pacu, *Piaractus mesopotamicus* Gill Tissue to a High Stocking Density: An Ion Regulatory and Microscopy Study**  
Wiolene Montanari Nordi, Debora Botequio Moretti, Mariana Caroline Pontin, Jessica Pampolini, Raul Machado-Neto  
Luiz de Queiroz College of Agriculture, University of São Paulo Brazil
- 5 Oral **Reversible Adsorption of Water Contaminants on Nanoporous Carbon Fibers**  
Sandrine Delpeux-Ouldriane, Mickael Gineys, Nathalie Cohaut, Francois BéGuin  
Centre National de la Recherche Scientifique France
- 6 Oral **Statistical Analysis of Polycyclic Aromatic Hydrocarbons Emissions and Its Alkyl and Nitro Derivatives from Diesel/Biodiesel Blends**  
Sergio Machado Correa  
Rio de Janeiro State University Brazil
- 7 Poster **Using Complete Soil Particle Size Distributions for More Precise Predictions of Soil Physical and Hydraulic Properties**  
Habib Khodaverdiloo, Fatemeh Afrasiabi, Farrokh Asadzadeh, Martinus Th. Van Genuchten  
Urmia University Iran, Islamic Republic Of
- 8 Oral **Hidden Markov Movement Modelling with Irregular Data**  
Victoria Goodall, Paul Fatti, Norman Owen-Smith  
Nelson Mandela Metropolitan University South Africa
- 9 Poster **Assessment of Bioaerosol and Microbial Volatile Organic Compounds in Different Sections of Library**  
Himanshu Lal, Bipasha Ghosh, Arun Srivastava  
Jawaharlal Nehru University India

**Interactions between Sodium Aerosols and Fission Products: A Theoretical Chemistry and Experimental**



## Presented papers

- 23 Oral **Cut-Out Animation as an Technic and Development inside History Process**  
Armagan Gokcearslan  
Gazi University Turkey
- 24 Oral **The Views of Teachers over the Father Involvement to Preschool Education Programs**  
Fatma Tezel Sahin, Zeynep Nur Aydin Kilic, Aysegul Akinci Cosgun  
Gazi University Turkey
- 25 Oral **Migration of Meaning in Contemporary Art Experience**  
K. Özlem Alp  
Gazi University Turkey
- 26 Oral **Space Figure Relationship in Contemporary Art**  
Selda Mant Menay  
Dumlupınar University Turkey
- 27 Oral **Types of Handmade Dolls in Turkey**  
Melda Özdemir  
Gazi University Turkey
- 28 Poster **Public-Public Partnership and Tourism Development Strategy: The Case of Municipality of Gazi Baba in Macedonia**  
Dejan Metodijeski, Elizabeta Mitreva, Nako Taskov, Oliver Filiposki  
University Goce Delcev Macedonia
- 29 Oral **A Fine String between Weaving the Text and Patching It: Reading beyond the Hidden Symbols and Antithetical Relationships in the Classical and Modern Arabic Poetry**  
Rima Abu Jaber-Bransi, Rawya Jarjoura Burbara  
Oranim Academic College Israel
- 30 Oral **A Sociolinguistic Analysis of Private Letters of Women in Ancient Egypt**  
Mariarosaria Zinzi  
University of Florence Italy
- 31 Oral **Hybrid Model of an Increasing Unique Consumer Value on Purchases that Influences the Consumer Loyalty and the Pursuit of a Sustainable Competitive Advantage from the Institutions in Jakarta**  
Wilhelmus Hary Susilo  
University of Persada Indonesia Indonesia



# Tokyo, October 11-12, 2017



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## ICGCGC 2017 : 19th International Conference on Geopolymer Cement and Geopolymer Concrete

Tokyo, Japan  
October 11 - 12, 2017





**Saint Petersburg, September 14-15, 2017**

# ICGC 2017 : 19th International Conference on Geopolymer Concrete

Saint Petersburg, Russia  
September 14 - 15, 2017

## Conference Information

[Aims and Objectives](#)

[Important Dates](#)

## International Scientific Committee

|                   |  |
|-------------------|--|
| Ahadollah Azami   | Eastern Mediterranean University, Famagusta City, North Cyprus, Turkey, TR |
| Xi Wang           | National Institute for Materials Science, JP                               |
| Thanh Nguyen P.   | Okayama University, JP   |
| Sherif El - Safty | National Institute for Materials Science, JP                               |
| Dmitriy Kuvshinov | University of Sheffield, UK  |



## Paper Submission

[Paper Submission](#)

[Paper Submission GUIDE](#)

## Conference Registration

[Author Registration](#)

[Listener Registration](#)

[Payment](#)

Yinghong Qin

Michigan Technological Univerisity, US

Anna Stepien

University of Technology, PL

Mahsa Armaghan

Azad University, Scienceand Research Branch, IR

Cheng-Yu Wang

National Chiao Tung University, TW

Mohammad Sajjad Nejad

Islamic Azad University, Borujerd, Iran, IR

Mohammed Mahmood

Diyala University, IQ

Heba Mansour

National Research Centre, EG

Rohit Kumar

National Institute of Technology, IN

Tiziano Zarra

University of Salerno, IT

Tahar Laoui

King Fahd University of Petroleum and Minerals, SA

Mohammed Mashrei

University of Thi-qar- Iraq, IQ

Asad Hanif

The Hong Kong University of Science and Technology, Hong Kong, HK

Olesia Mikhailova

Brno University of Technology, Czech Republic

Mohamed Gabr

Kanazawa Institute of Technology, Japan

Nor Salwati Othman

Universiti Tenaga Nasional, Malaysia

Uche Okafor

University of Nigeria, Nigeria



# **Beware of fake geopolymer conferences**

Organisations such as WASET run fake “conferences” in order to make profit with the registration fees (450-500 USD), often under the names of real conferences.

I am confident that all researchers and members of the geopolymer science community will immediately realise that WASET’s conferences are void of any scientific value.

Please spread the word among your contacts so that nobody mistakenly participates to such fake conferences!



# **State of the Geopolymer R&D 2017**

- 1) Geopolymer science**
- 2) Geopolymer technologies**
- 3) Geopolymer Cements / Concretes**
- 4) Geopolymer and archaeology**



# State of the Geopolymer R&D 2017

## 1) Geopolymer science

2) Geopolymer technologies

3) Geopolymer Cements / Concretes

4) Geopolymer and archaeology



# Why Alkali-Activated Materials (AAM) are not Geopolymers ?

Because

Alkali-activated Materials are not POLYMERS.

They cannot be called GEO-POLYMERS

2 very different systems!

It is a big scientific mistake to use both as synonyms.

*Alkali-activation is a wrong terminology for geopolymers.*



# Why Alkali-Activated Materials (AAM) are not Geopolymers ?

## Part 4

***Legal and Patent issue !***



## **Question** From Danemark :

I did my Master thesis on geopolymer cement for oil well cementing (with focus on High Temperatures). Waiting an offer for Geopolymer Concrete PhD from UTS (Sydney). Interested to know how much room for new patents is available (many companies asked me).

---

Example Geopolymer-Cement:  
trial (patent lawsuit) at European Patent Office.

Red Lion Cement Technology Ltd  
vs PQ and BASF (world chemistry companies);



Davidovits  
patent filed in  
France, July  
**2006**

(12) **United States Patent**  
Davidovits et al.

(10) **Patent No.:** US 8,202,362 B2  
(45) **Date of Patent:** Jun. 19, 2012

(54) **GEOPOLYMERIC CEMENT BASED ON FLY  
ASH AND HARMLESS TO USE**

(56)

References Cited

**2012**

U.S. PATENT DOCUMENTS

(57) **ABSTRACT**

Geopolymeric cement based on aluminosilicate fly ashes of class F, which, contrary to the prior art, are harmless to use and harden at ambient temperature, favoring their use in common applications in the construction and civil engineering fields. This harmlessness is achieved thanks to a mixture containing: 10 to 15 parts by weight of a non corrosive alkali metal silicate solution in which the  $M_2O:SiO_2$  molar ratio is less than 0.78, preferably less than 0.69 and the  $SiO_2:M_2O$  ratio greater than 1.28, preferably greater than 1.45, M denoting Na or K; added to this are 10 to 20 parts by weight of water and 5 to 15 parts by weight of blast furnace slag having a specific surface area less than  $400\text{ m}^2/\text{kg}$  preferably less than  $380\text{ m}^2/\text{kg}$  and 50 to 100 parts by weight of class F aluminosilicate fly ash.

**MR>1.45  
User Friendly**





**2010**



(11) **EP 2 061 732 B1**

(12) **FASCICULE DE BREVET EUROPEEN**

(45) Date de publication et mention  
de la délivrance du brevet:  
**28.04.2010 Bulletin 2010/17**

(21) Numéro de dépôt: **07823342.6**

(22) Date de dépôt: **26.07.2007**

(51) Int Cl.:  
**C04B 28/00** <sup>(2006.01)</sup> **C04B 18/08** <sup>(2006.01)</sup>

(86) Numéro de dépôt international:  
**PCT/FR2007/001285**

(87) Numéro de publication internationale:  
**WO 2008/012438 (31.01.2008 Gazette 2008/05)**

---

(54) **CIMENT GÉOPOLYMÉRIQUE À BASE DE CENDRES VOLANTES ET À GRANDE INNOCUITÉ  
D'EMPLOI.**

UNSCHÄDLICHER GEOPOLYMERZEMENT AUF DER BASIS VON FLUGASCHE  
GEOPOLYMERIC CEMENT BASED ON FLY ASH AND HARMLESS TO USE



**April 2010** : European Patent granted

9 months grace period

**February 2011** : Opposition by BASF and PQ Corp.

based on alkali-activation = geopolymer

i.e. public domain, not patentable

**24 November 2014** : EPO Judgment EPatent = OK



**December 2014** : BASF appeal of decision

repeating claim alkali-activated materials = geopolymer

= public domain, not patentable

**January 23, 2017** : Appeal trial



**Beschwerdekammern  
Boards of Appeal  
Chambres de recours**

European Patent Office  
80298 MUNICH  
GERMANY  
Tel. +49 (0)89 2399-0  
Fax +49 (0)89 2399-4465





СОЮЗ СОВЕТСКИХ  
СОЦИАЛИСТИЧЕСКИХ  
РЕСПУБЛИК

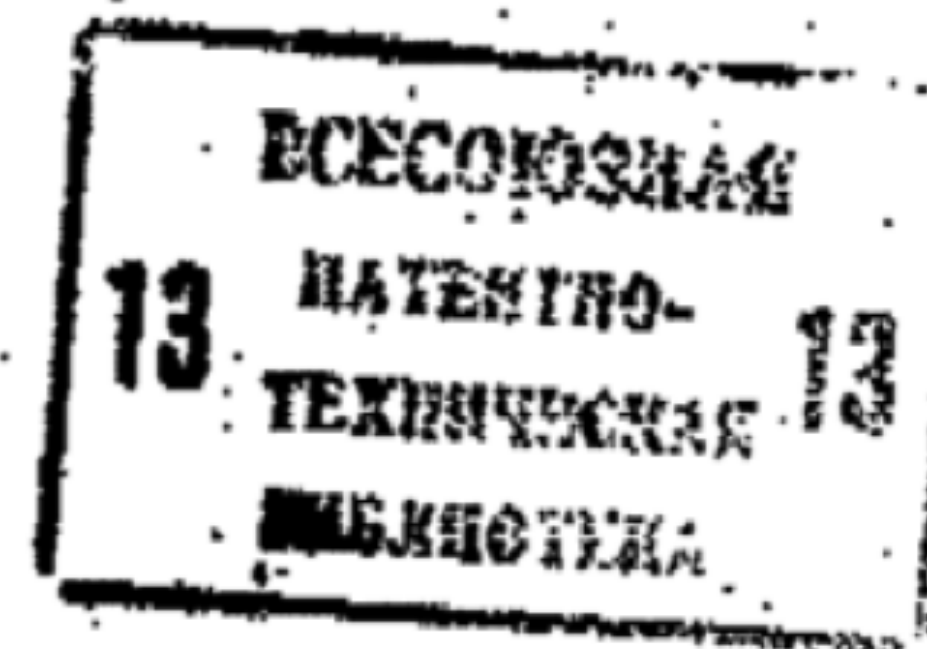
(19) SU (11) 1008182 A

3 (5D) С 04 В 7/14

ГОСУДАРСТВЕННЫЙ КОМИТЕТ СССР  
ПО ДЕЛАМ ИЗОБРЕТЕНИЙ И ОТКРЫТИЙ

# ОПИСАНИЕ ИЗОБРЕТЕНИЯ

## К АВТОРСКОМУ СВИДЕТЕЛЬСТВУ



Filed 1981, Published 1983

Krivenko

(21) 3354207/29-33  
 (22) 04.11.81  
 (46) 30.03.83. Бюл. № 12  
 (72) И.А. Пашков, С.И. Чурсин,  
 П.В. Кривенко и Е.С. Кавалерова  
 (71) Киевский ордена Трудового Крас-  
 ного Знамени инженерно-строительный  
 институт  
 (53) 666.943(088.8)  
 (56) 1. Авторское свидетельство СССР  
 № 772989, кл. С 04 В 7/14, 1979.  
 2. Авторское свидетельство СССР  
 № 419489, кл. С 04 В 7/14, 1972.

(54) (57) ВЯЖУЩЕЕ, включающее домен-  
 ный гранулированный шлак, раствори-  
 мое стекло и золу-унос, отличаю-  
 щееся тем, что, с целью  
 увеличения сроков схватывания, повы-  
 шения прочности и снижения объемной  
 массы, оно содержит указанные компо-  
 ненты в следующем соотношении, вес. %:

|                   |       |
|-------------------|-------|
| Доменный гранули- |       |
| рованный шлак     | 50-67 |
| Растворимое       |       |
| стекло            | 8-15  |
| Зола-унос.        | 25-35 |



(54) (57) BINDER, comprising granulated blast-furnace slag, water glass and fly ash, characterized in that with the object of increasing setting times, enhancing strength and reducing bulk weight, it comprises said components in the following ratio, wt.%:

|                               |       |
|-------------------------------|-------|
| Granulated blast-furnace slag | 50-67 |
| Water glass                   | 8-15  |
| Fly ash                       | 25-35 |

**MR=1.0  
corrosive,  
User Hostile**

Boards of Appeal of European Patent Office

**January 23, 2017 :**

appeal rejected.

all BASF claims were defeated, European patent valid

i.e. alkali activation AAM lost against geopolymer



Basic chemistry is in Public Domain.

Alkali activated materials AAM not patentable,

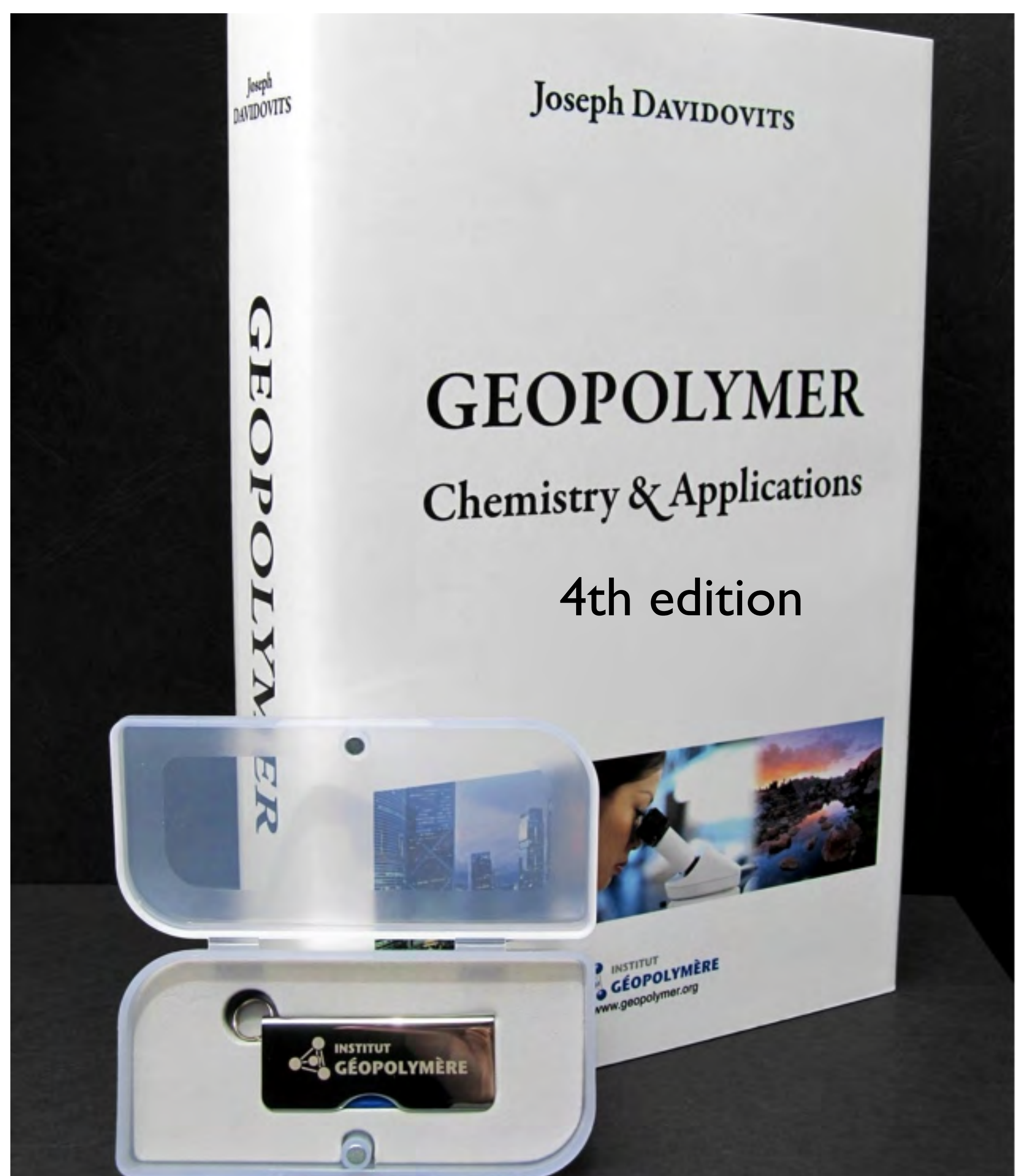
Geopolymer materials,  
patentable when based on new science.



Metakaolin MK-750  
Chemical Reactivity

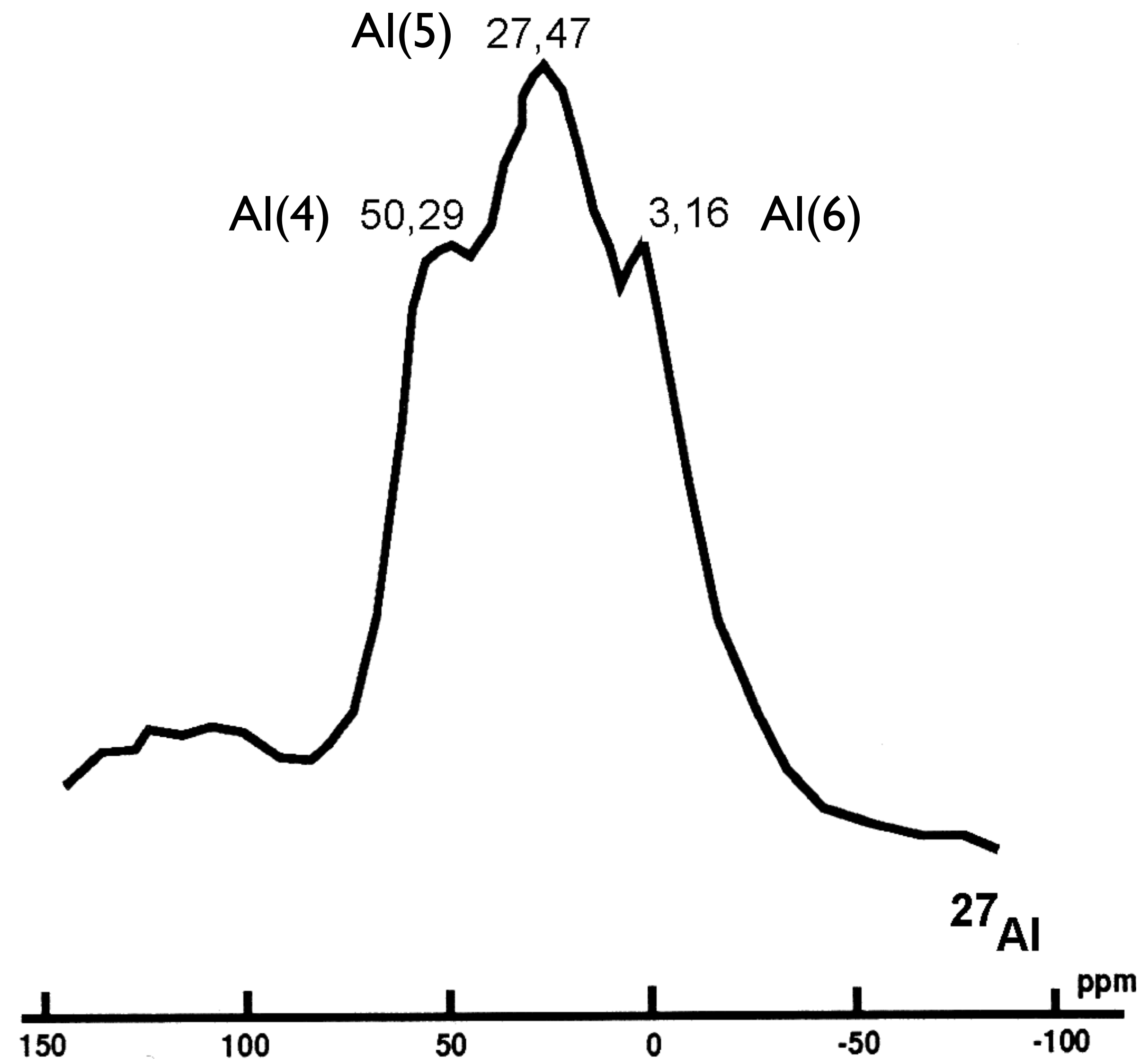
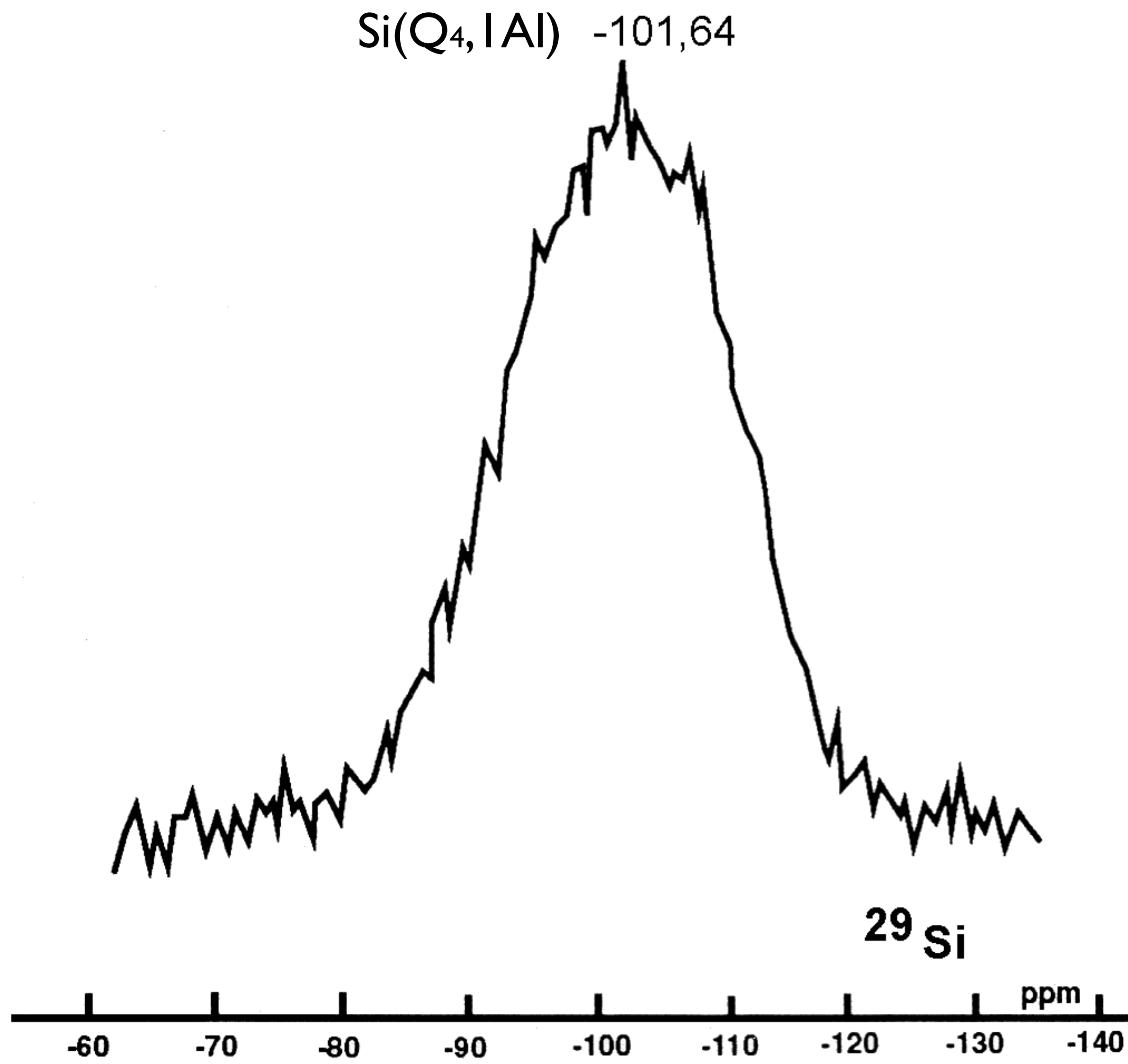
Exothermicity

Chapter 8

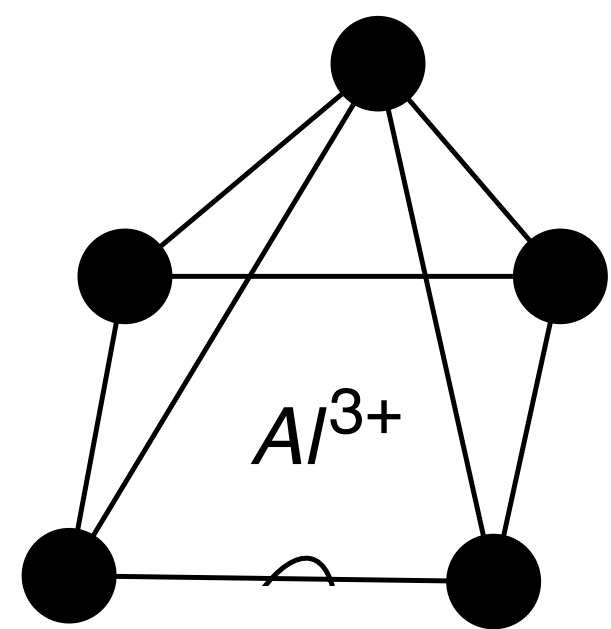




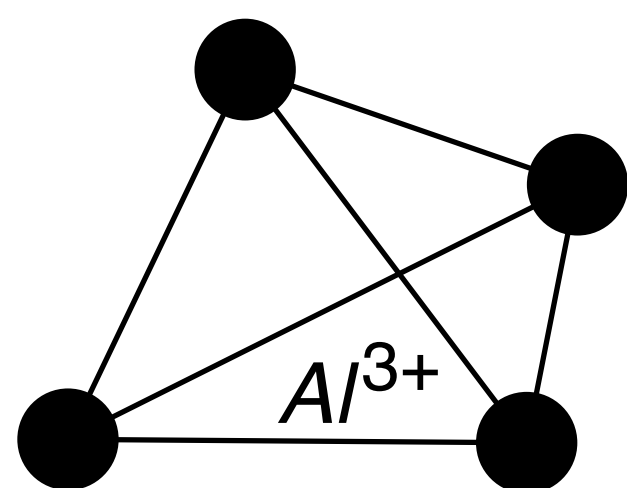
# MK-750 NMR



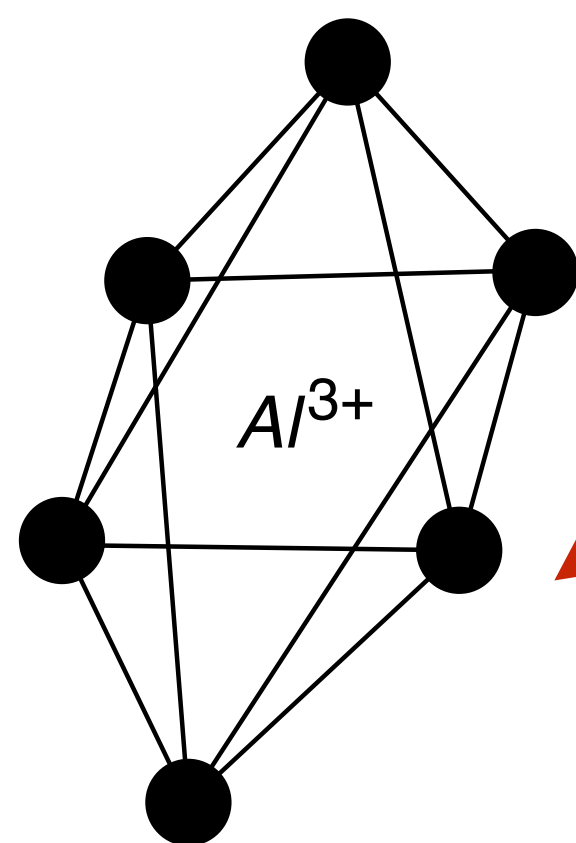




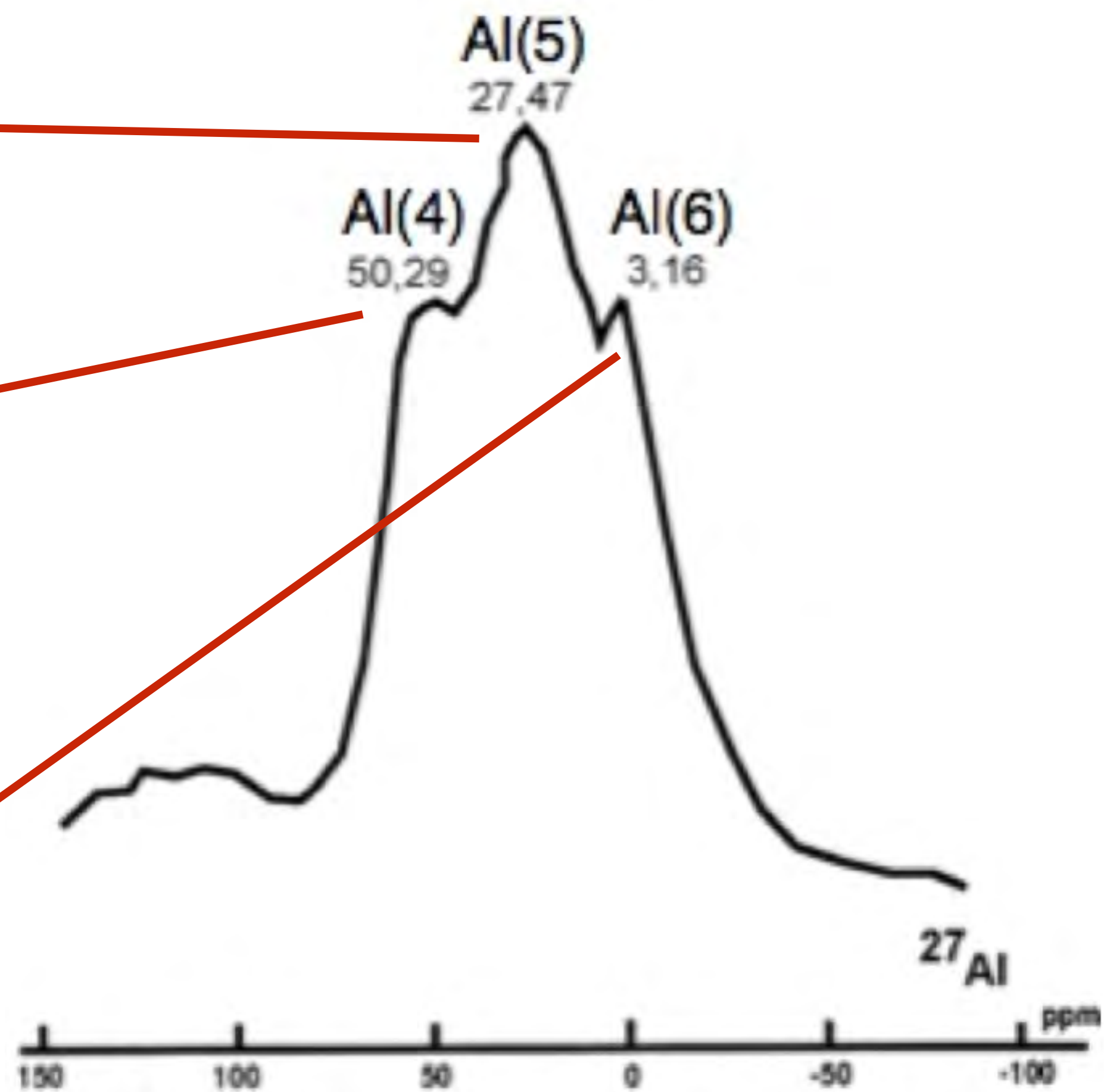
**Al(5)**



**Al(4)**



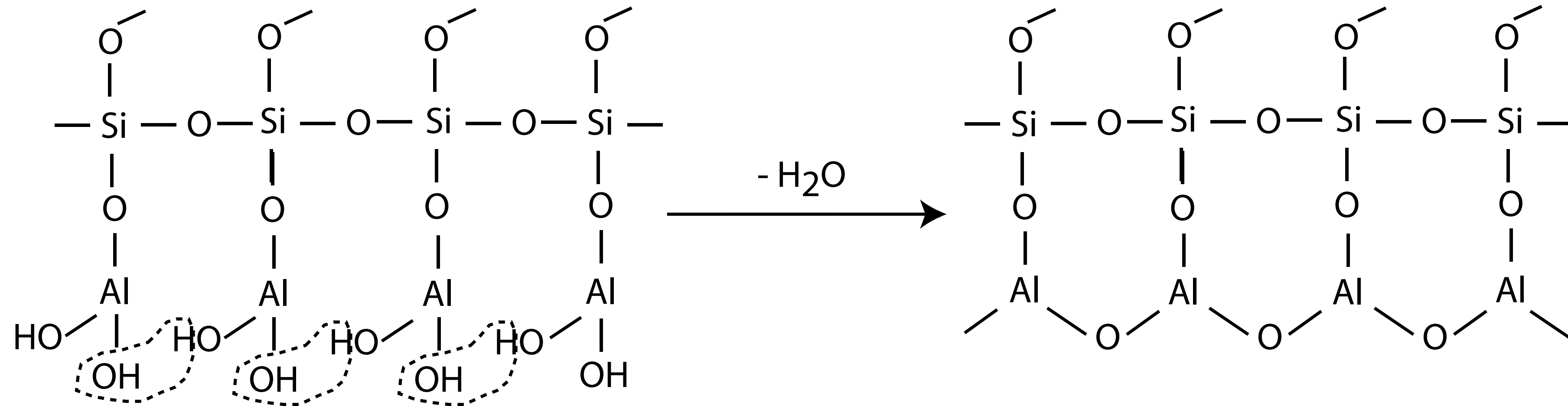
**Al(6)**



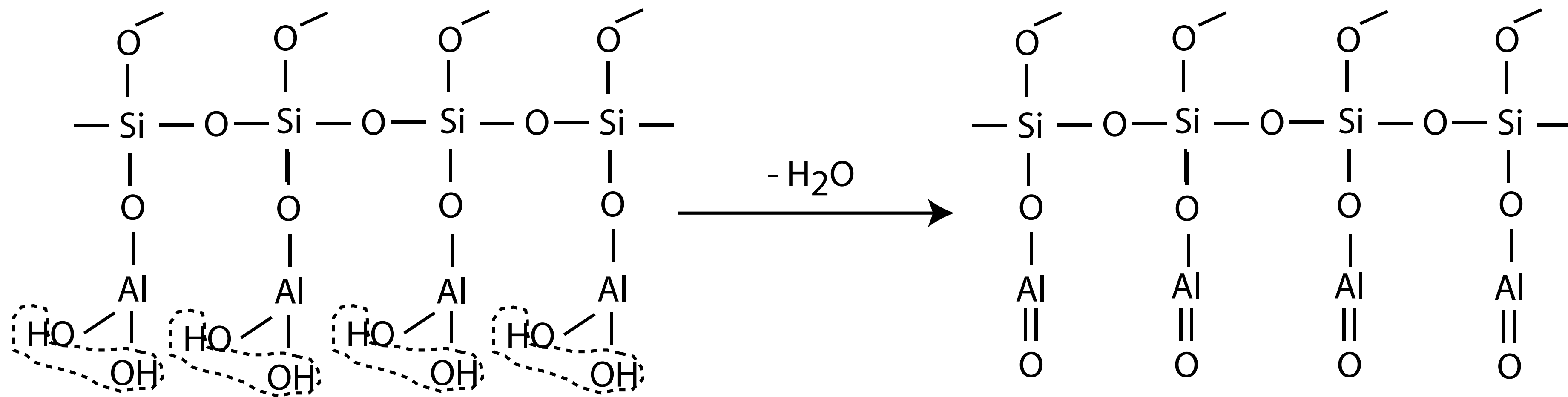
**MK-750 Al NMR**



# Making of metakaolin MK-750



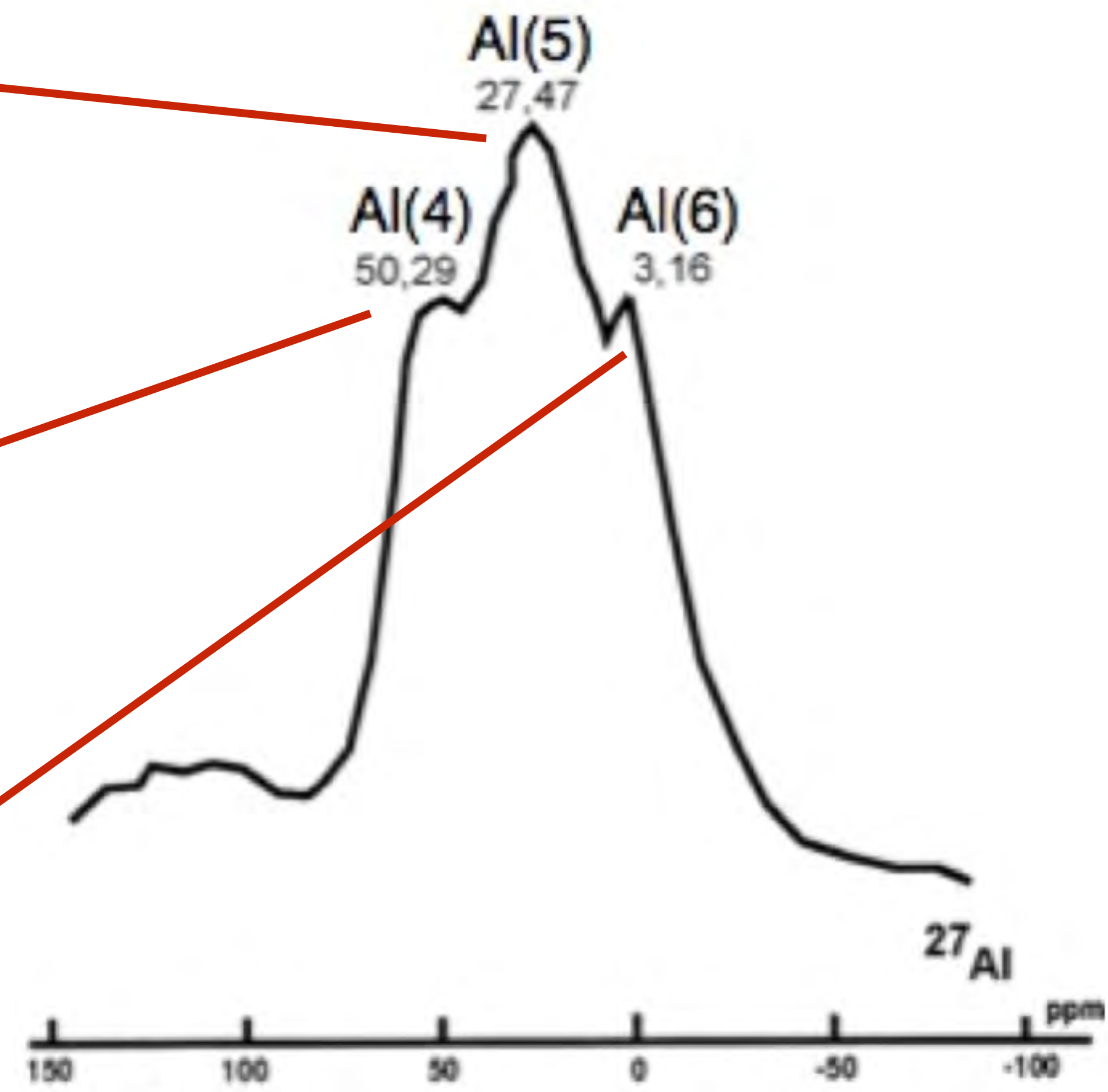
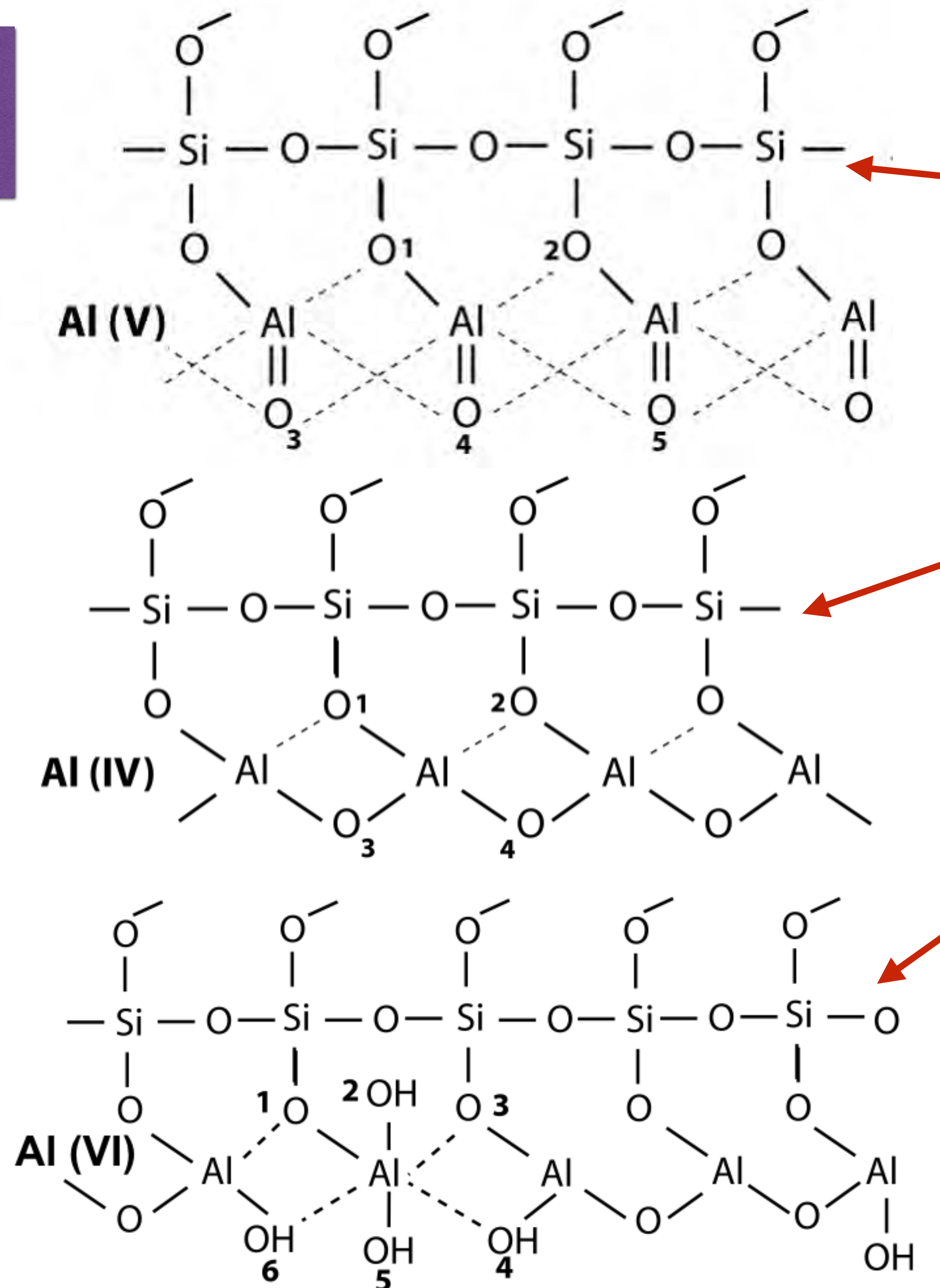
Inter-dehydroxylation



Intra-dehydroxylation

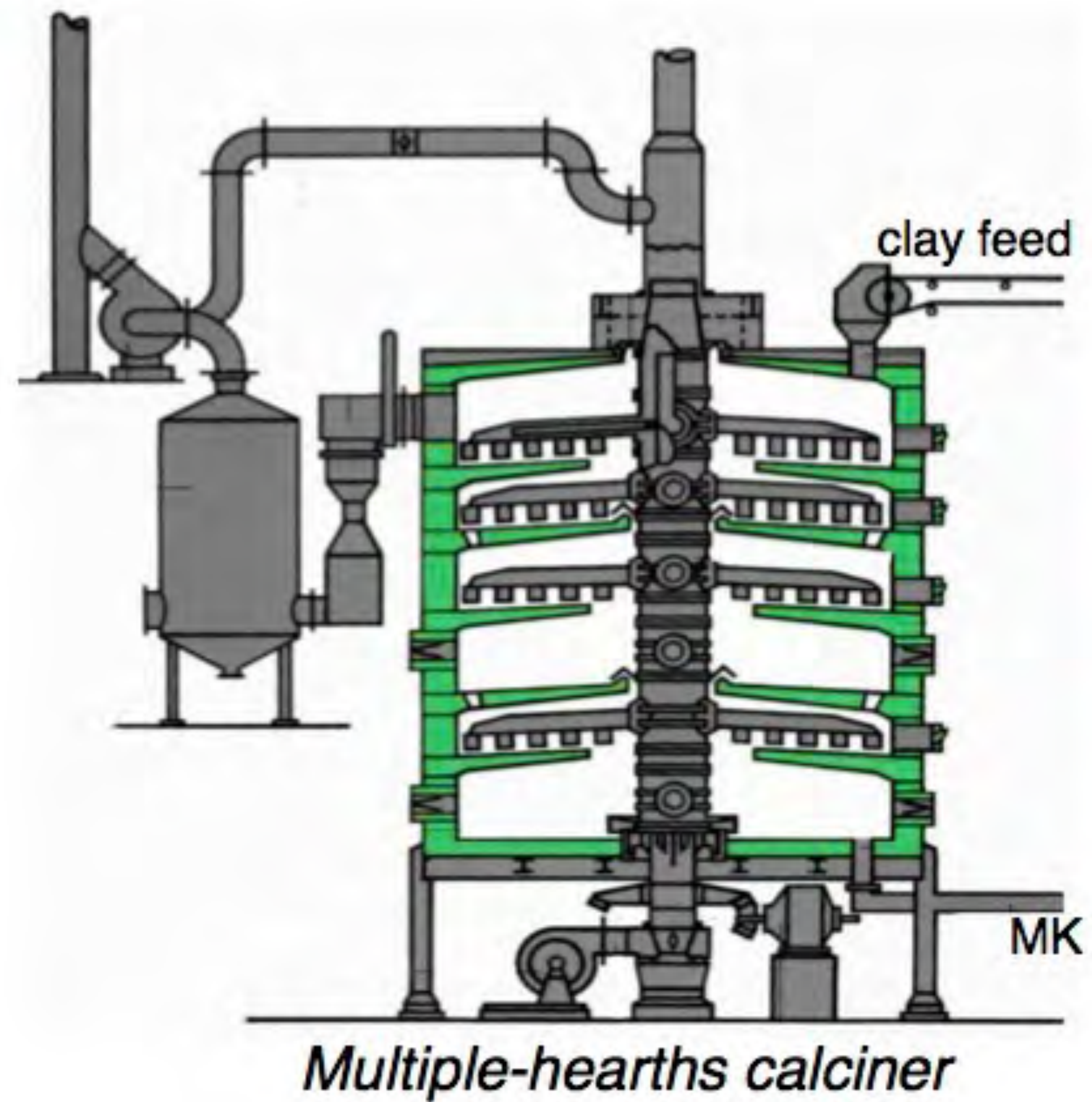
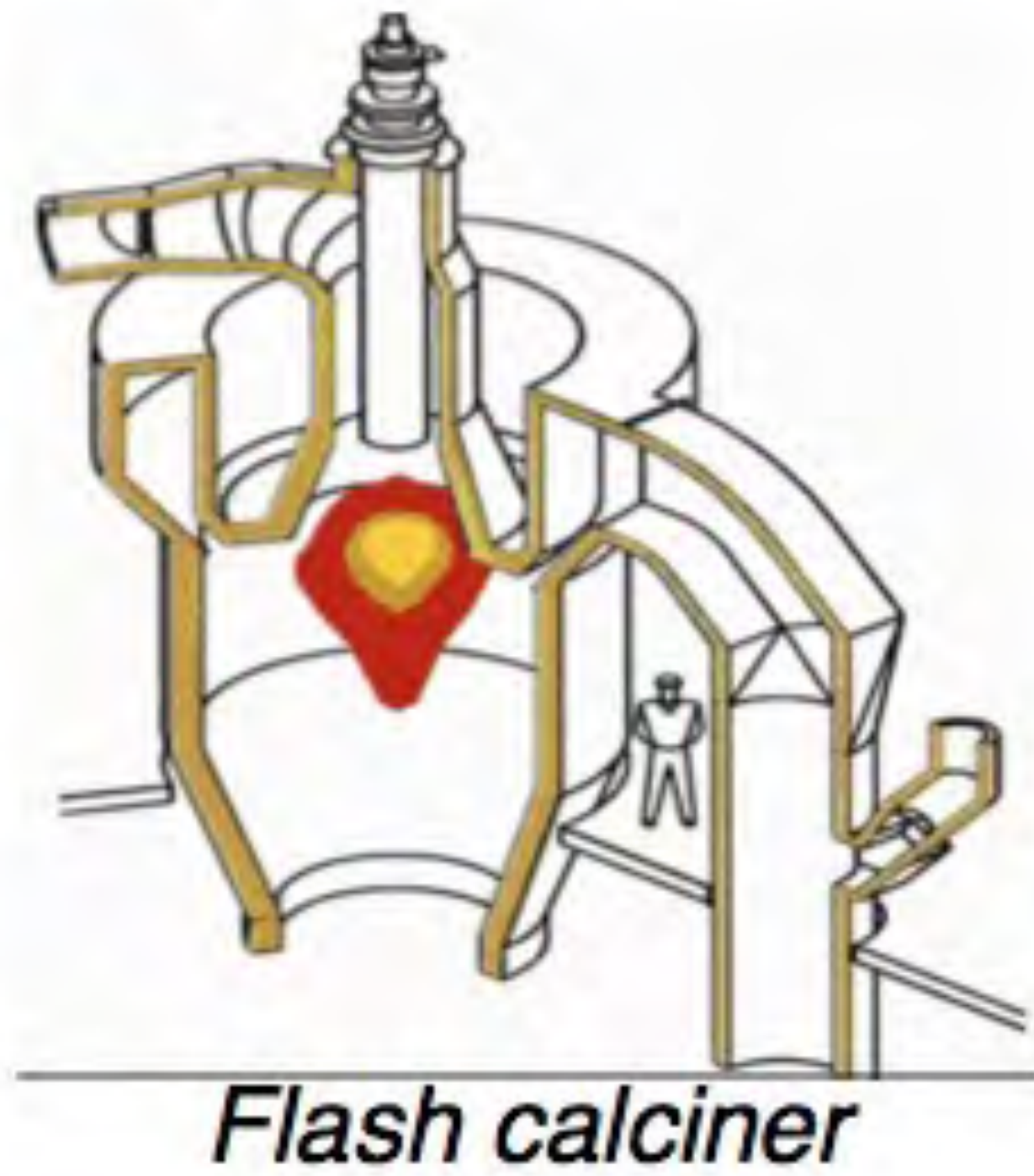
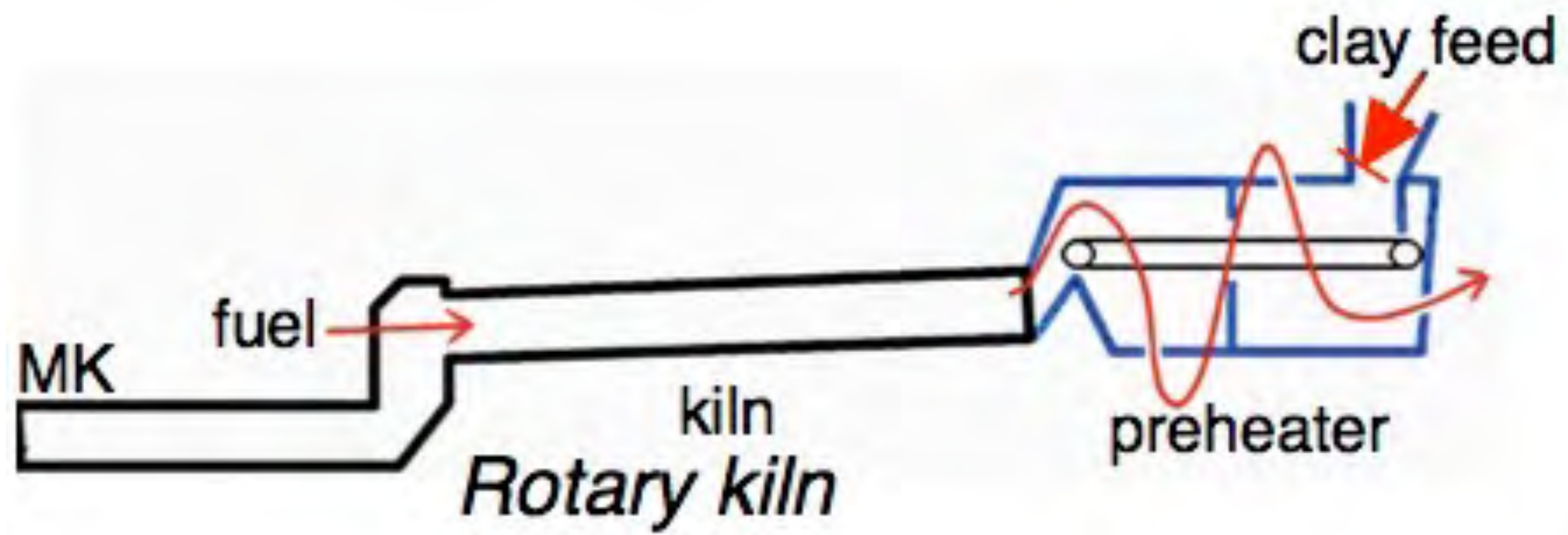


**Al is trivalent**



**MK-750 Al NMR**

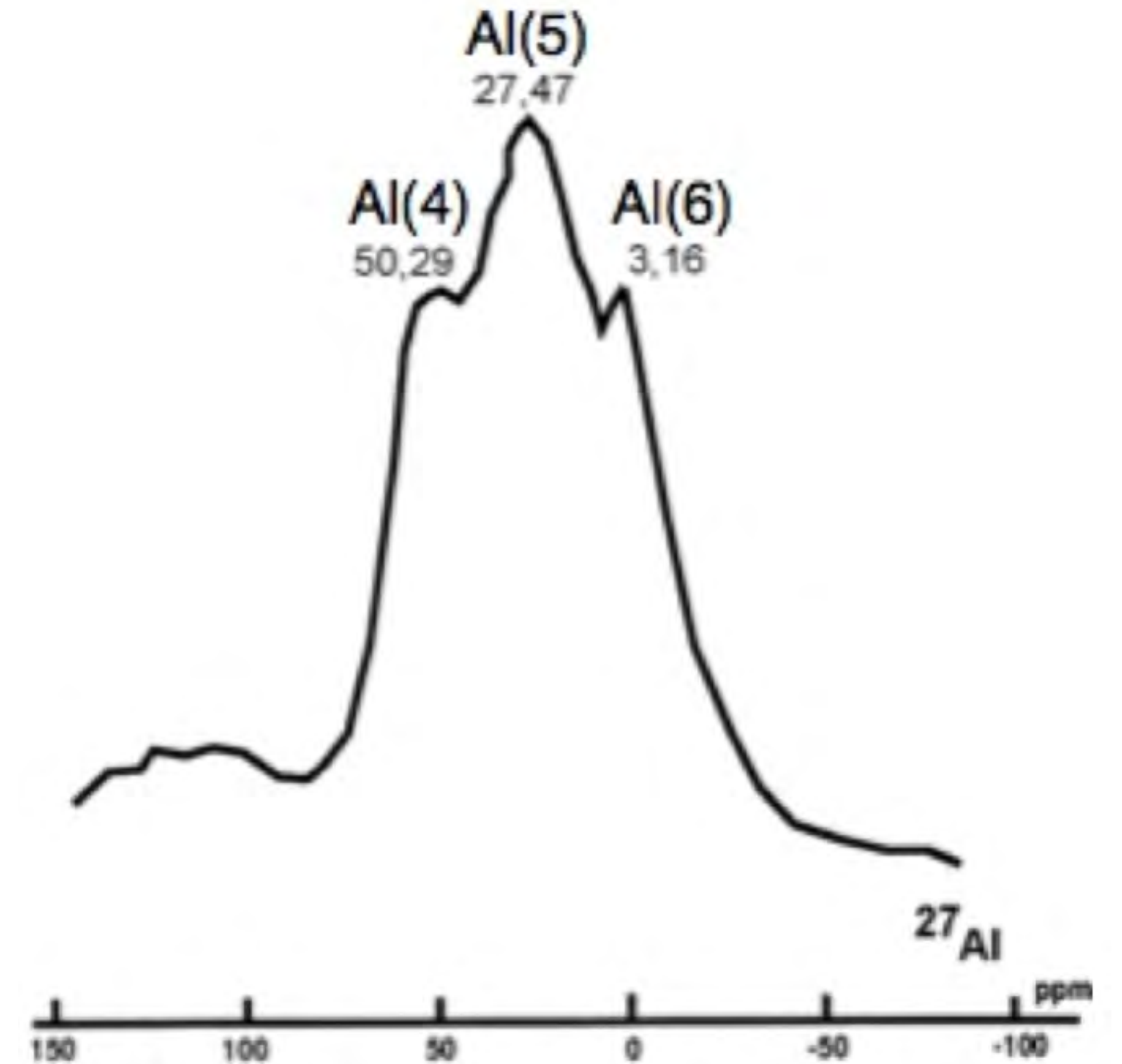






# $^{27}\text{Al}$ MAS-NMR

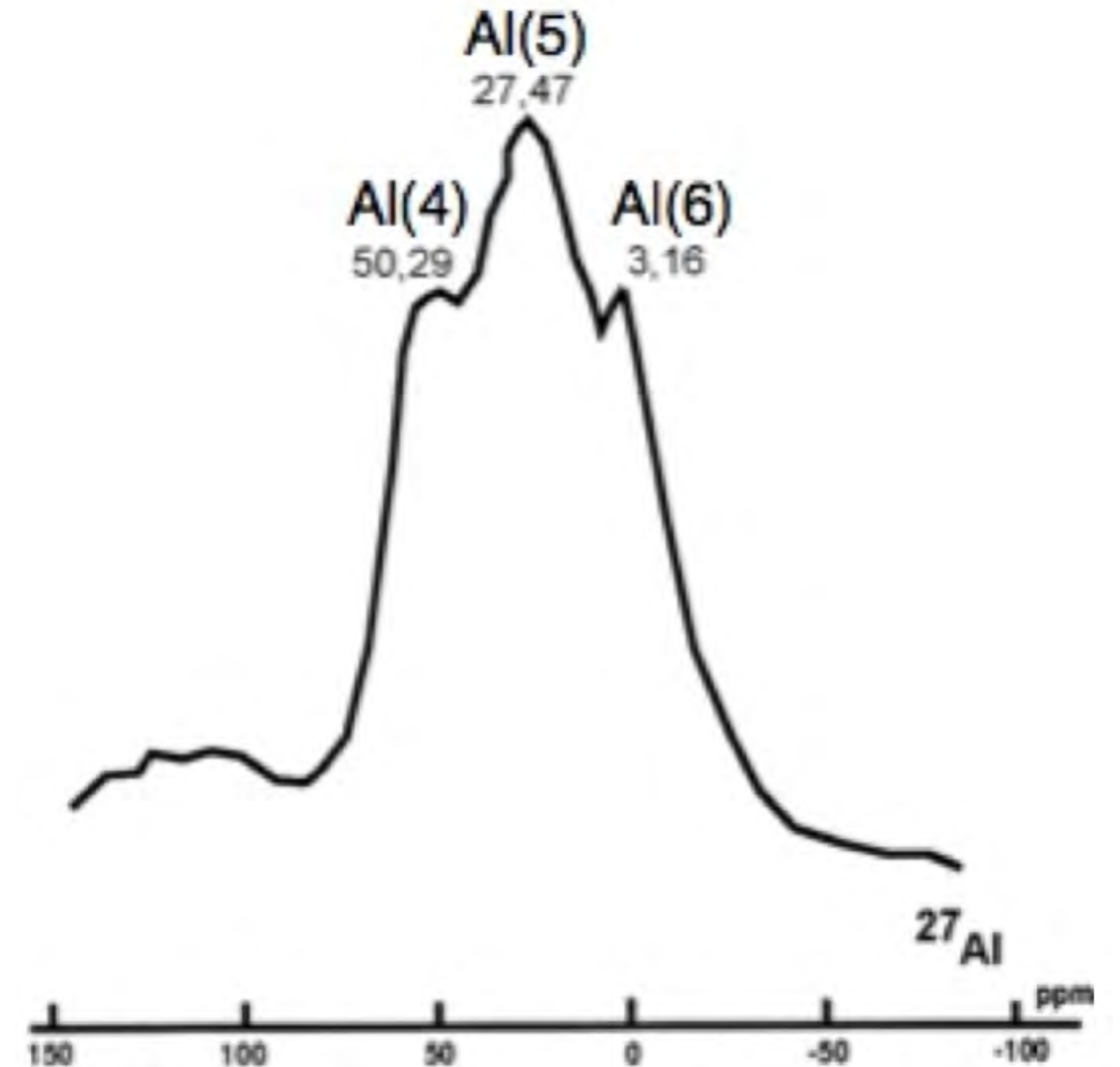
| Kiln type               | Al-OH<br>Al(6) % | Al=O<br>Al(5) % | Al-O-Al<br>Al(4) % | Al(5) + Al(4)<br>reactivity % |
|-------------------------|------------------|-----------------|--------------------|-------------------------------|
| <b>Rotary<br/>M1000</b> | <b>35</b>        | <b>50</b>       | <b>15</b>          | <b>65</b>                     |





# $^{27}\text{Al}$ MAS-NMR

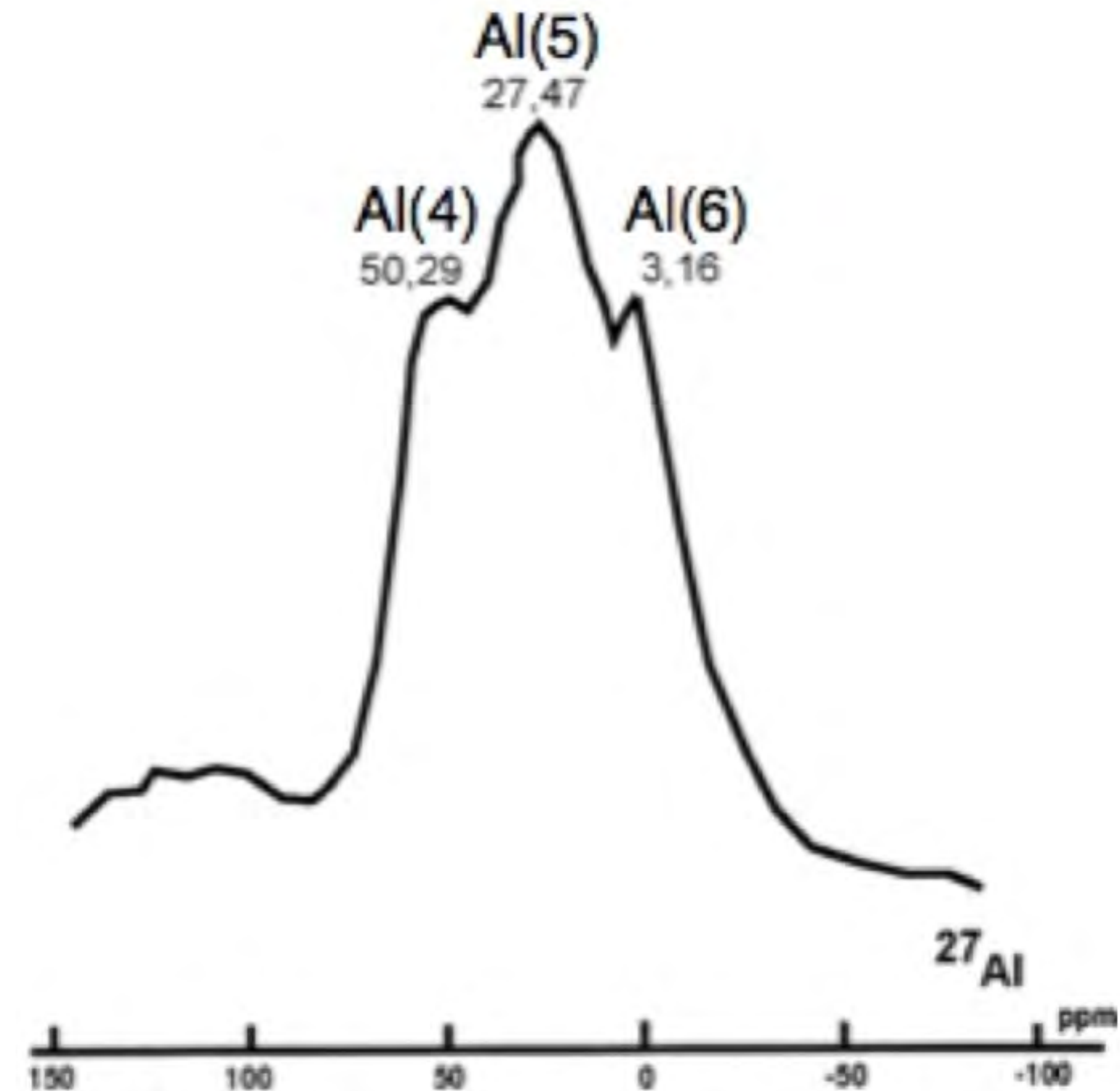
| Kiln type              | Al-OH<br>Al(6) % | Al=O<br>Al(5) % | Al-O-Al<br>Al(4) % | Al(5) + Al(4)<br>reactivity % |
|------------------------|------------------|-----------------|--------------------|-------------------------------|
| <i>Rotary</i><br>M1000 | 35               | 50              | 15                 | 65                            |
| <i>Flash</i><br>M1200S | 25               | 55              | 20                 | 75                            |





# $^{27}\text{Al}$ MAS-NMR

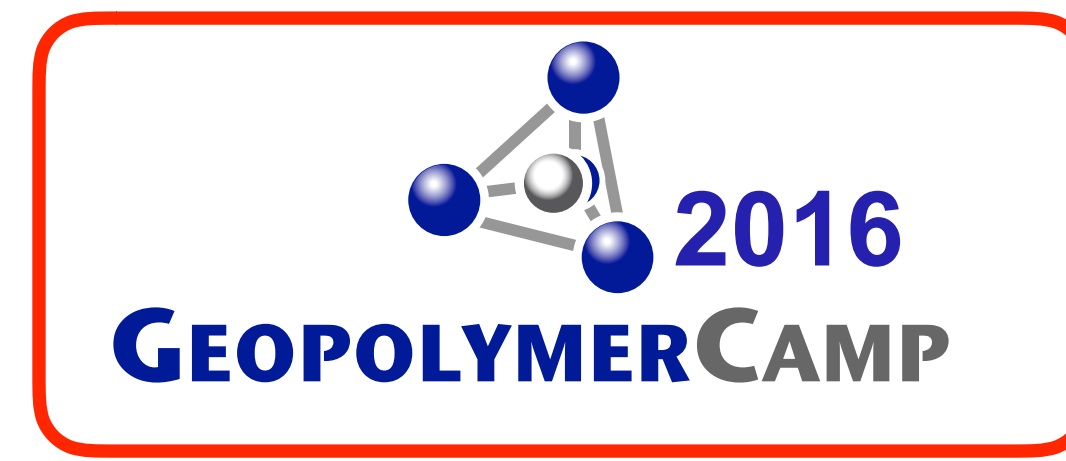
| Kiln type                          | Al-OH<br>Al(6) % | Al=O<br>Al(5) % | Al-O-Al<br>Al(4) % | Al(5) + Al(4)<br>reactivity % |
|------------------------------------|------------------|-----------------|--------------------|-------------------------------|
| <b>Rotary</b><br>M1000             | <b>35</b>        | <b>50</b>       | <b>15</b>          | <b>65</b>                     |
| <b>Flash</b><br>M1200S             | <b>25</b>        | <b>55</b>       | <b>20</b>          | <b>75</b>                     |
| <b>Vertical</b><br>MetaStar<br>501 | <b>24</b>        | <b>49</b>       | <b>27</b>          | <b>76</b>                     |







*Christine Pélegris  
Axel Compere*



Pragmatic approach  
in designing a high-performance  
geopolymer ceramic  
in a 3D printed mould

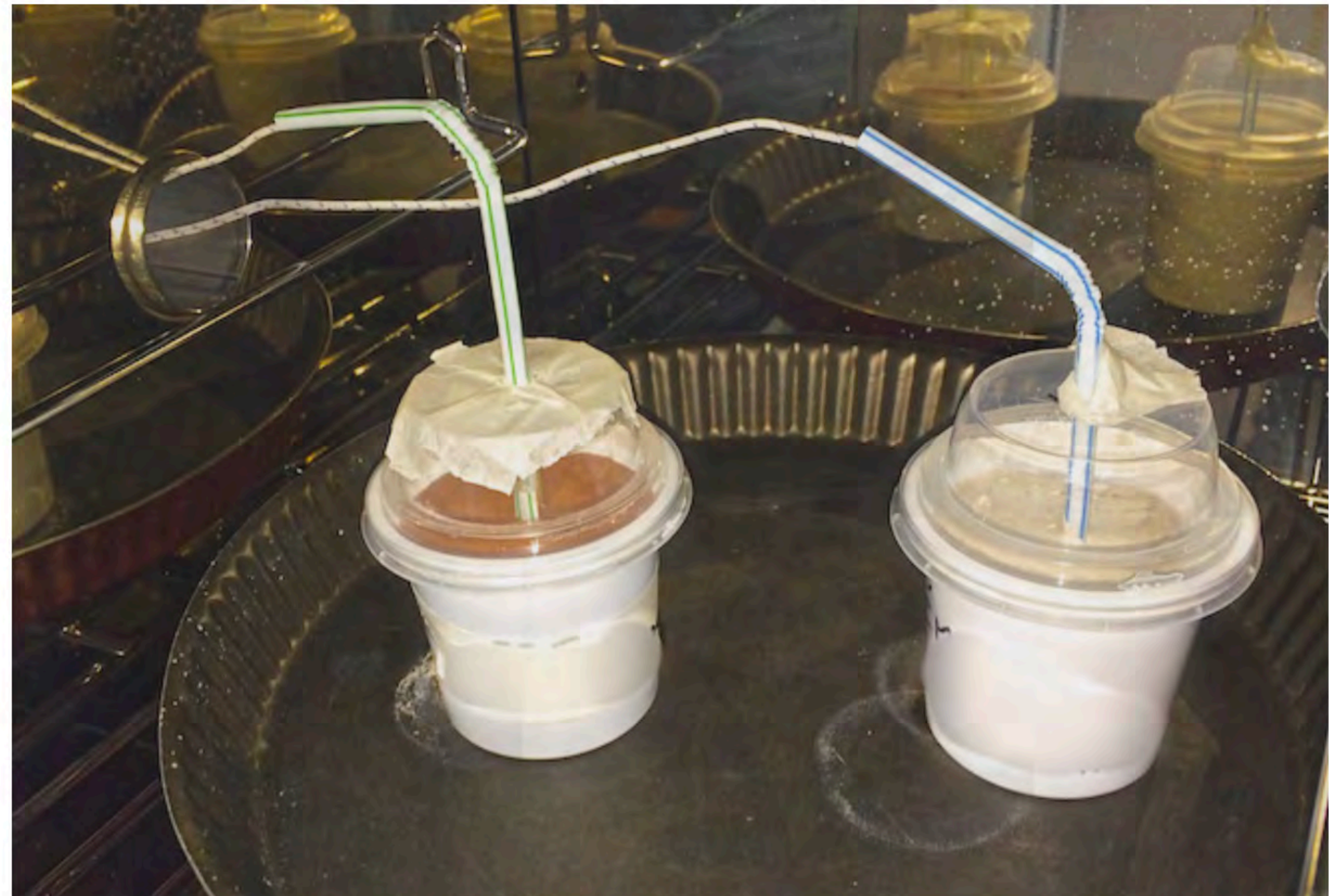
*From theory to practice*

Poly(sialate-siloxo) type K-PSS resin



# Reactivity test, observing exothermicity

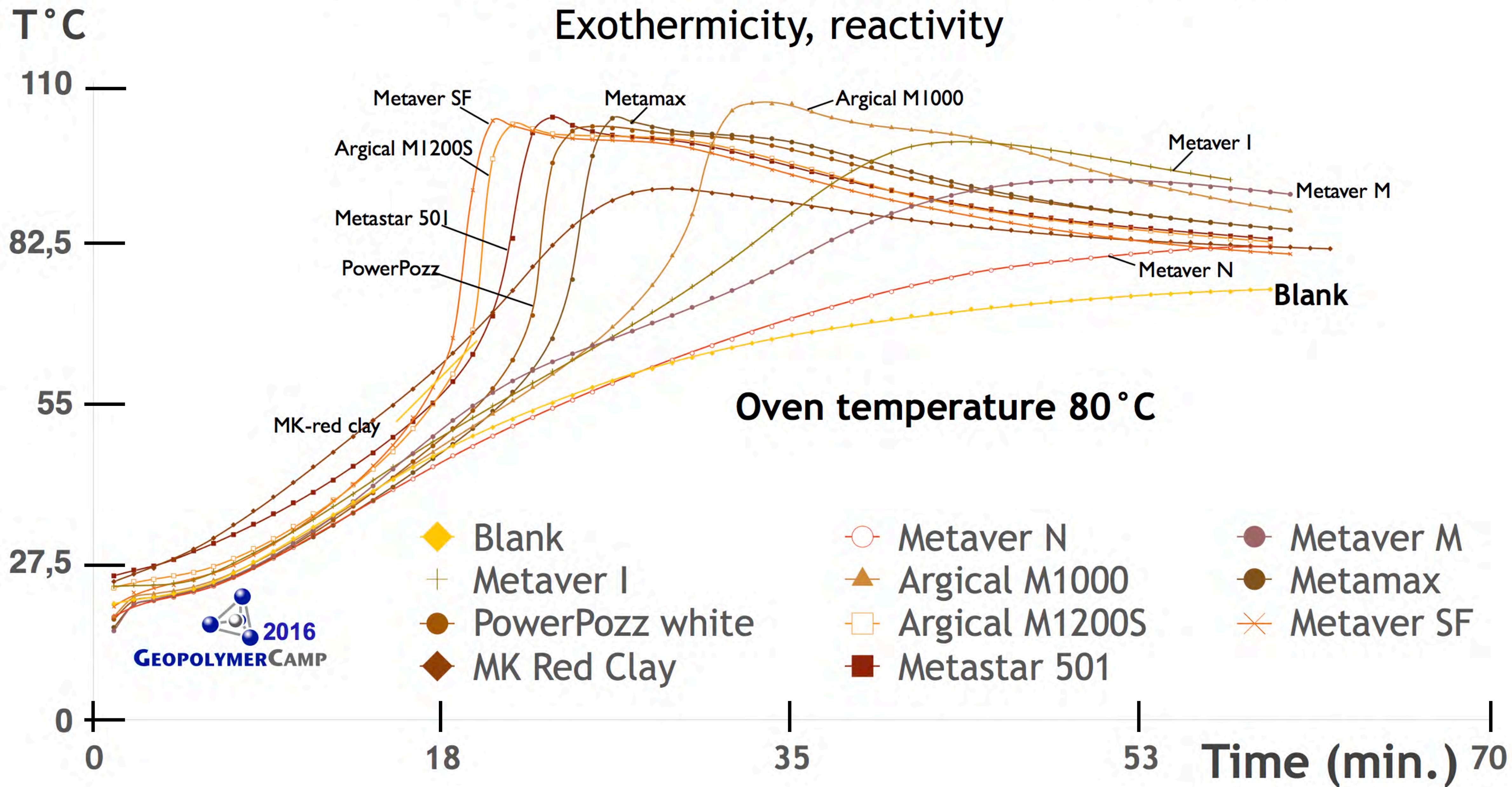
see: *J. Davidovits, Geopolymer Chemistry and Applications, Chapter 8.*





# Testing of 10 commercial metakaolins

## Exothermicity, reactivity







*Christine Pélegris  
Nadine Ngoungoure  
Florient Rousseau*



*Ralph Davidovits*

***2017 lab. studies***

**Designing high-performance  
MK-750-based geopolymers.**

***Poly(sialate-siloxo) type K-PSS binder***

**From theory to practice**



# State of the Geopolymer R&D 2017

1) Geopolymer science

**2) Geopolymer technologies**

3) Geopolymer Cements / Concretes

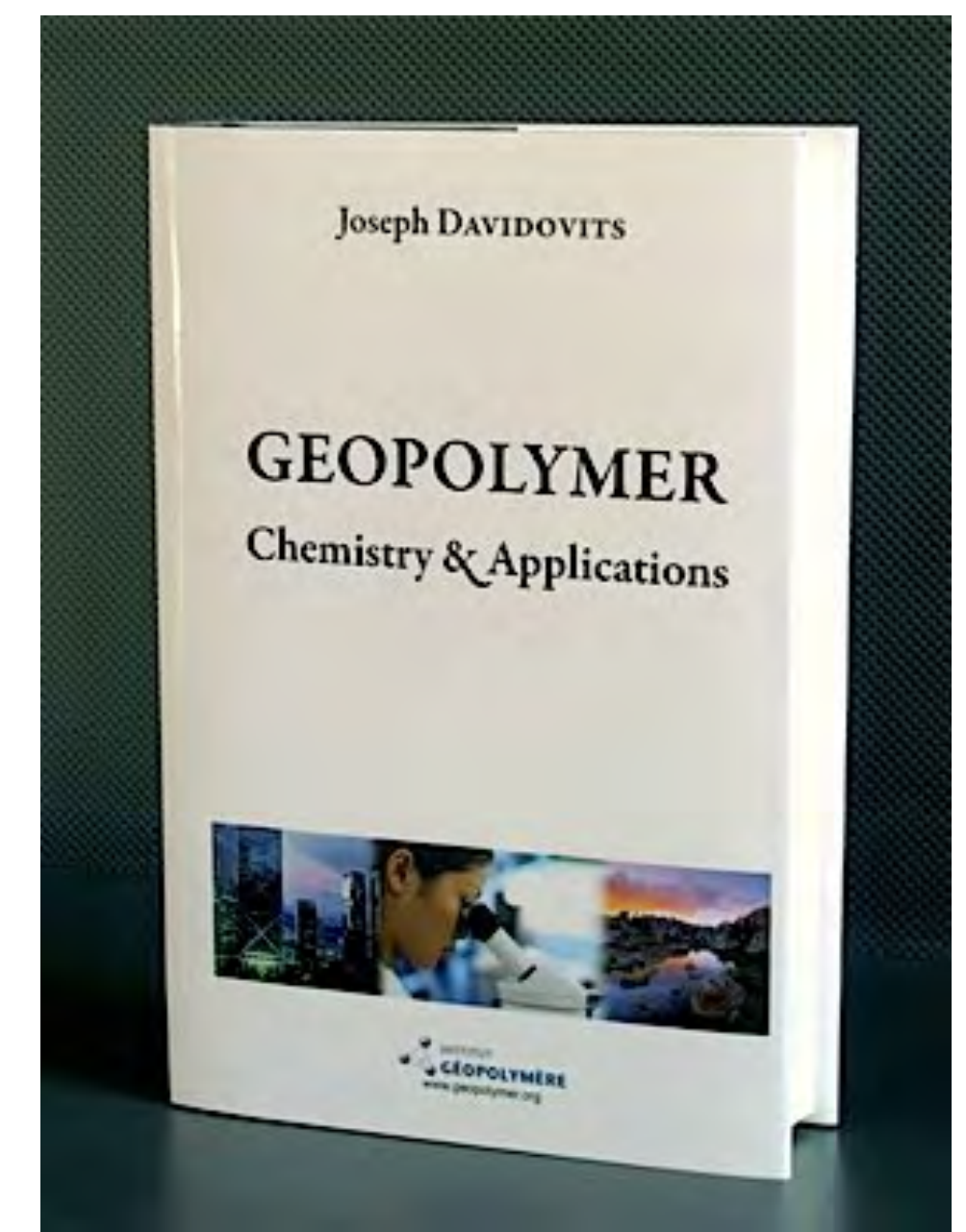
4) Geopolymer and archaeology



# Geopolymer Route to High-Temperature Ceramics

See Chapter 23

## Keynote Prof. W. Kriven



MK-750 based Geopolymers can be converted to a high strength ceramic material on heating:

- Sodium geopolymers crystallize into nepheline  $\text{NaAlSi}_2\text{O}_6$  on heating to  $900^\circ\text{C}$ – $1100^\circ\text{C}$
- Potassium geopolymers crystallize into leucite  $\text{KAlSi}_2\text{O}_6$  on heating to  $900^\circ\text{C}$ – $1200^\circ\text{C}$ ,
- Cesium geopolymers crystallize into pollucite  $\text{CsAlSi}_2\text{O}_6$  on heating to  $\sim 1050^\circ\text{C}$ .

These ceramic materials have unusual properties such as refractoriness ( $1693^\circ\text{C}$ – $1940^\circ\text{C}$ ), relatively low density and high fracture toughness. Their properties enable these geopolymer ceramics to be used as reinforcements in thermal barrier coatings or to increase toughness in glass-ceramics.



# Synthesis and Characterization of Silicon Carbide Powders Converted from Metakaolin-Based Geopolymer

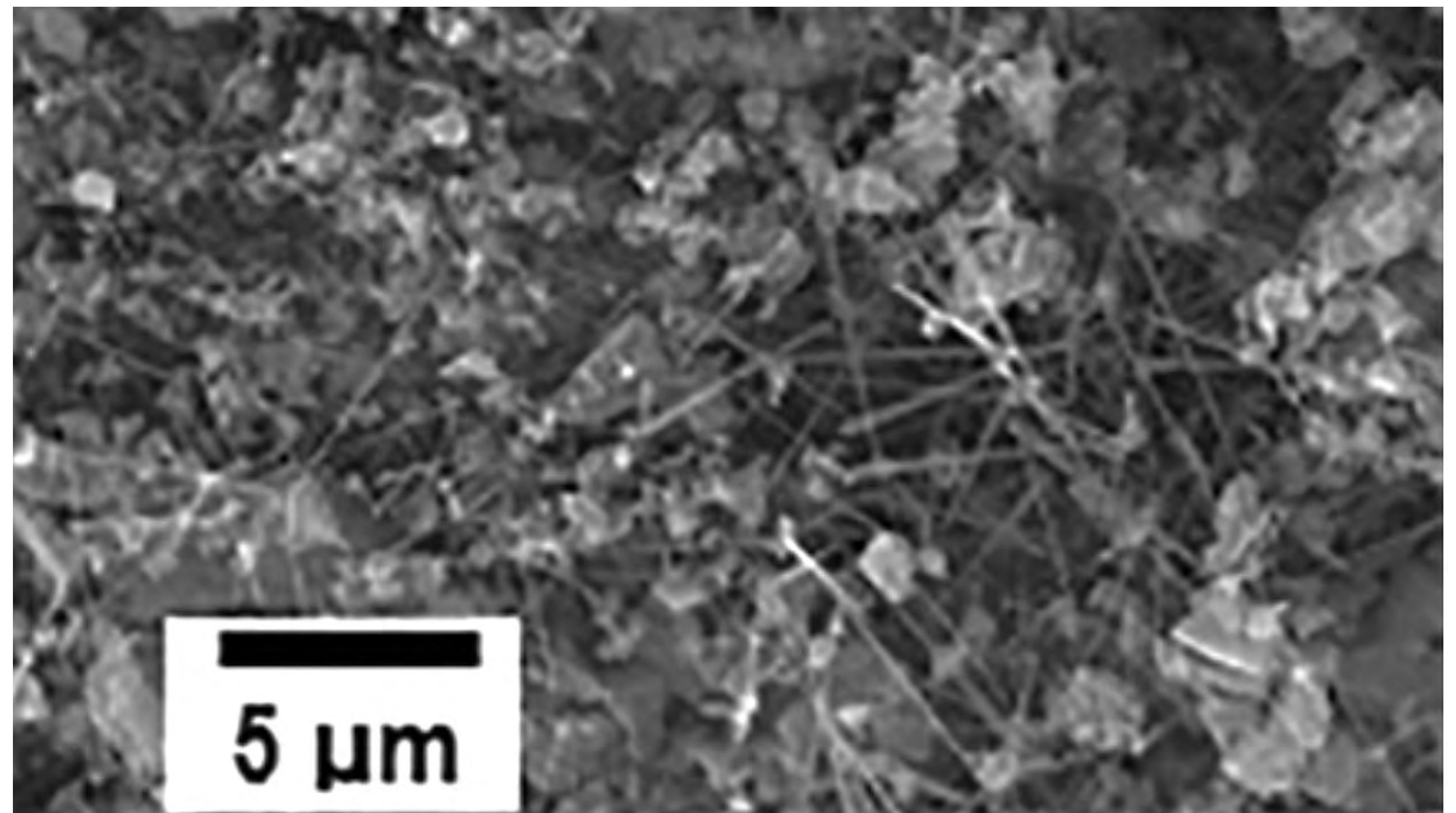
Cengiz Bagci,<sup>‡,§,†</sup> Gregory P. Kutyla,<sup>‡</sup> Kevin C. Seymour,<sup>‡</sup> and Waltraud M. Kriven<sup>‡</sup>

<sup>‡</sup>Department of Materials Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801

<sup>§</sup>Department of Metallurgical and Materials Engineering, Faculty of Engineering, Hitit University, Corum 19030, Turkey

SEM micrographs of KGP-18C/ 2 h after being fired to 1500°C, in flowing argon, with needle-like morphology.

No extremely high temperature (e.g., 2500°C) needed as for the traditional process.







Tuesday, July 11, 2017

**Focused session: Geopolymer composites**





# 3rd Virtual Journal on Geopolymer Science

May 31 2016



**ELSEVIER**



The third issue of what will become the Virtual Journal on Geopolymer Science is online at

**Reinforced Geopolymer Composites**

**A critical review**

The *Virtual Journal on Geopolymer Science* is a collection of already published research



# Reinforced Geopolymer Composites: A critical review

31 May 2016 | Joseph Davidovits

31 May 2016

This critical review is the follow up of two feature articles titled *Geopolymers based on natural and synthetic metakaolin*, (on line on 17 January 2016) and *Environmental implications of Geopolymers*, (online on 20 June 2015). It has been written in compliance with a decision of Elsevier and Geopolymer Institute to join forces, distill and distribute the best research publications contained in their combined archives, through a series of **Elsevier-Geopolymer Institute Virtual Special Issues on Geopolymer Science**. On line 29 June 2015.

The invention of mineral geopolymers of the types poly(sialate) -Si-O-Al-O- (Si:Al=1), poly(sialate-siloxo) -Si-O-Al-O-Si-O- (Si:Al=2), poly(sialate-disiloxo) -Si-O-Al-O-Si-O-Si-O- (Si:Al=3), poly(sialate-multisiloxo) (Si:Al>>3) goes back to 1972, when, in the aftermath of various catastrophic fires in France causing hundreds of casualties in public buildings which involved common organic plastic, research on non-flammable and non-combustible plastic materials became our priority.

We founded a private research company in 1972, Cordi SA (called later Cordi-Géopolymère), to develop new inorganic fire-resistant polymer materials which we called «geopolymers» (mineral polymers resulting from geochemistry or geosynthesis). We knew that we would not reach fire resistance and zero toxicity with organic chemistry. When, ten years later, we started the development of a geopolymer matrix composite concept, the objective was to fabricate molding tools and patterns, to replace metal tooling for small production runs in the plastic processing industry and the foundry industry. The targeted working

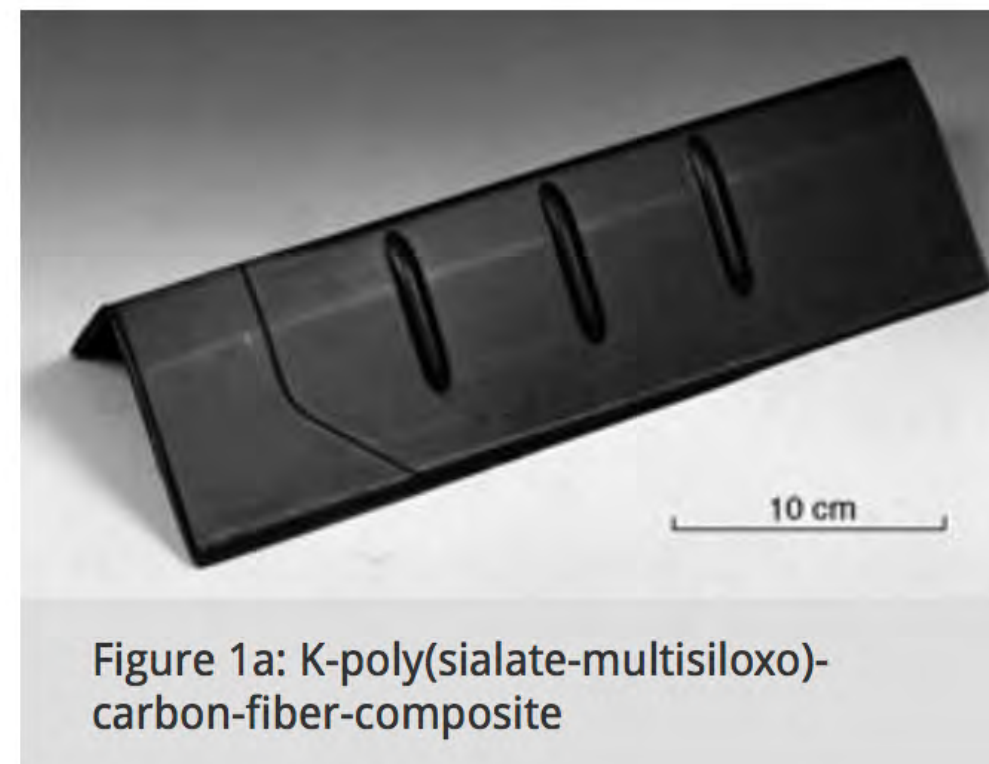


Figure 1a: K-poly(sialate-multisiloxo)-carbon-fiber-composite

## Features

Polymers and soft materials

Nanomaterials

Surface science



## You might also like...

REVIEW

### Additive manufacturing of multi-directional preforms for composites: opportunities and challenges

Volume 18, Issue 9, Pages 503–512 |

Zhenzhen Quan, Amanda Wu, Michael Keefe, Xiaohong Qin, Jianyong Yu, Jonghwan Suhr, Joon-Hyung Byun, Byung-Sun Kim, Tsu-Wei Chou

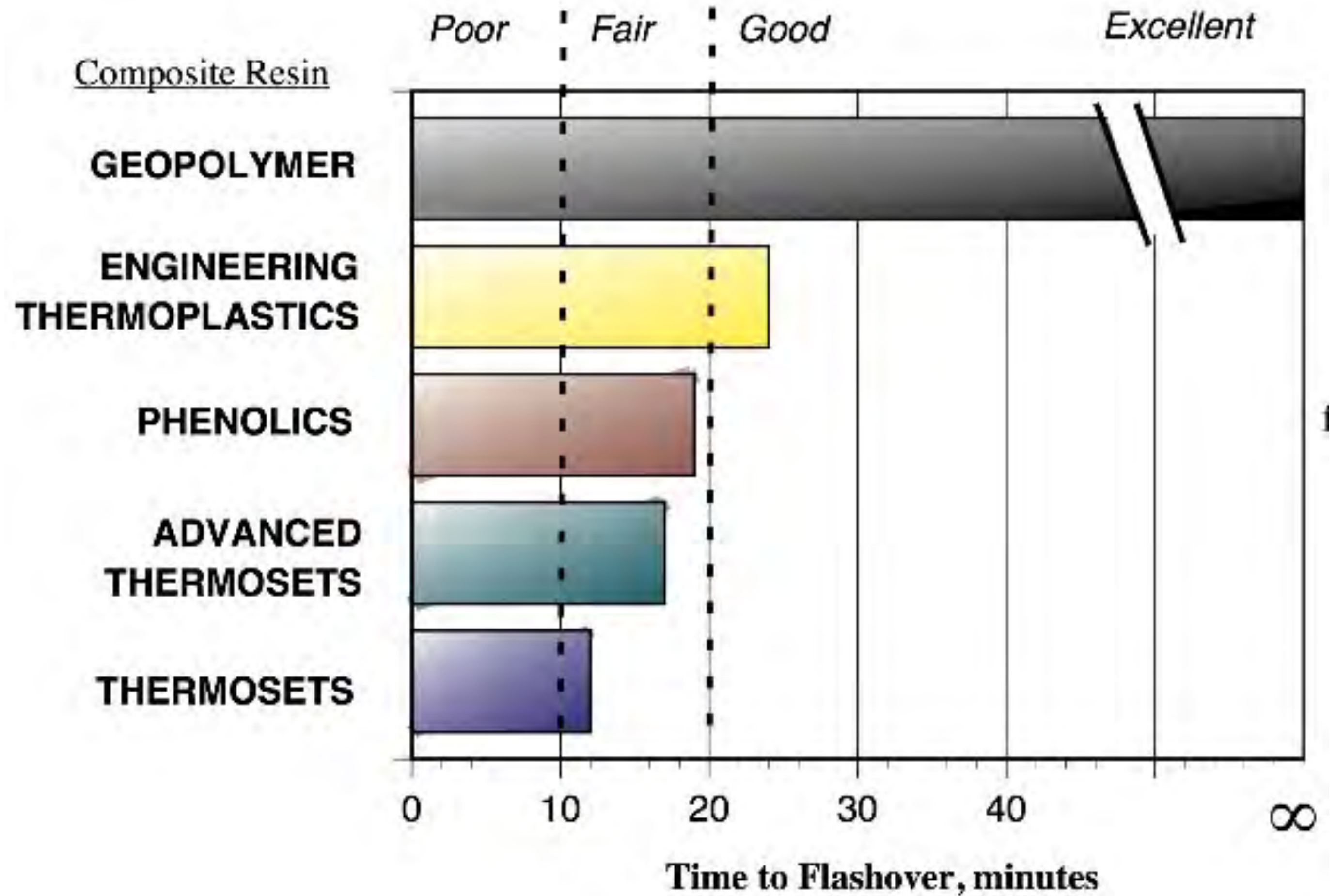
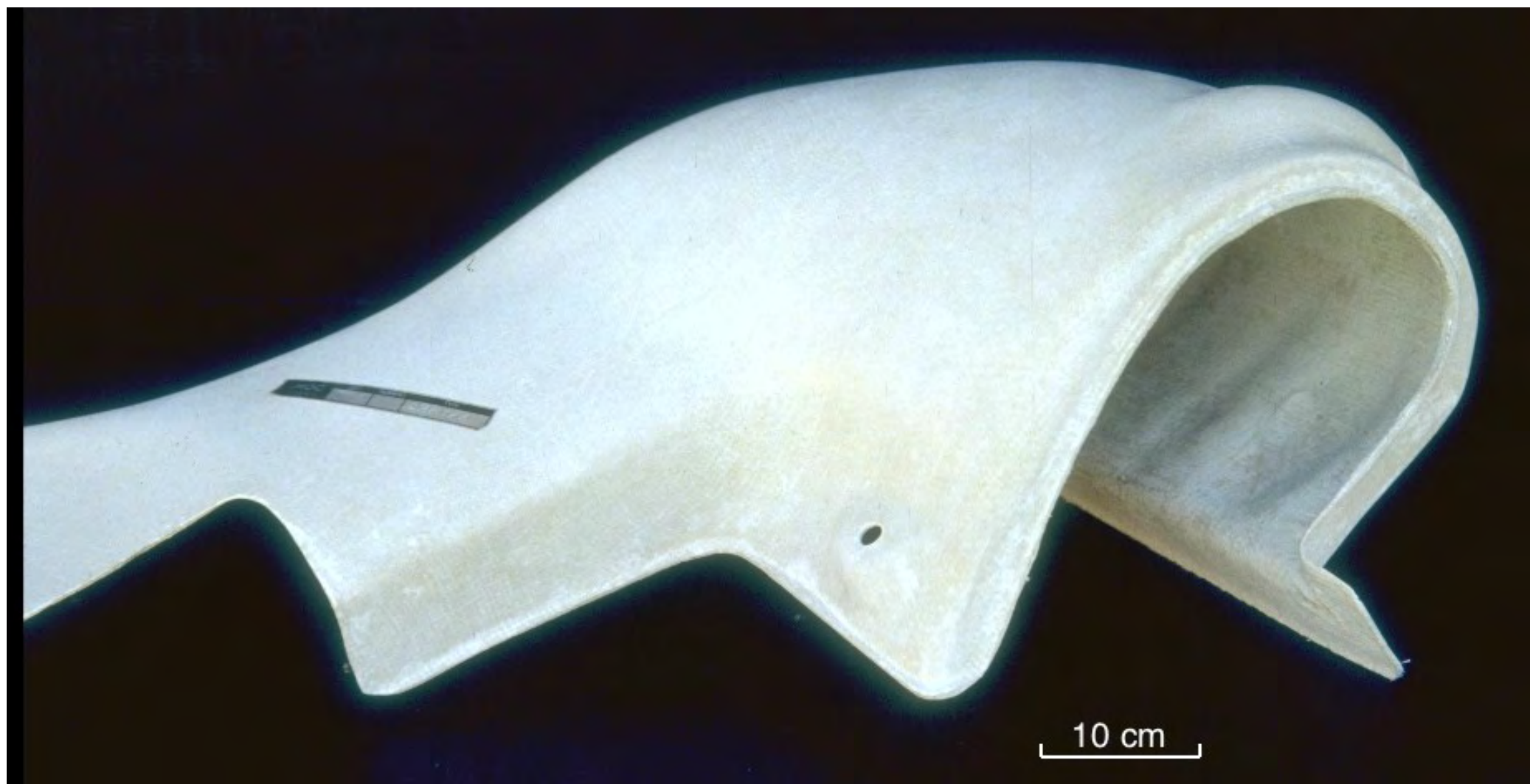
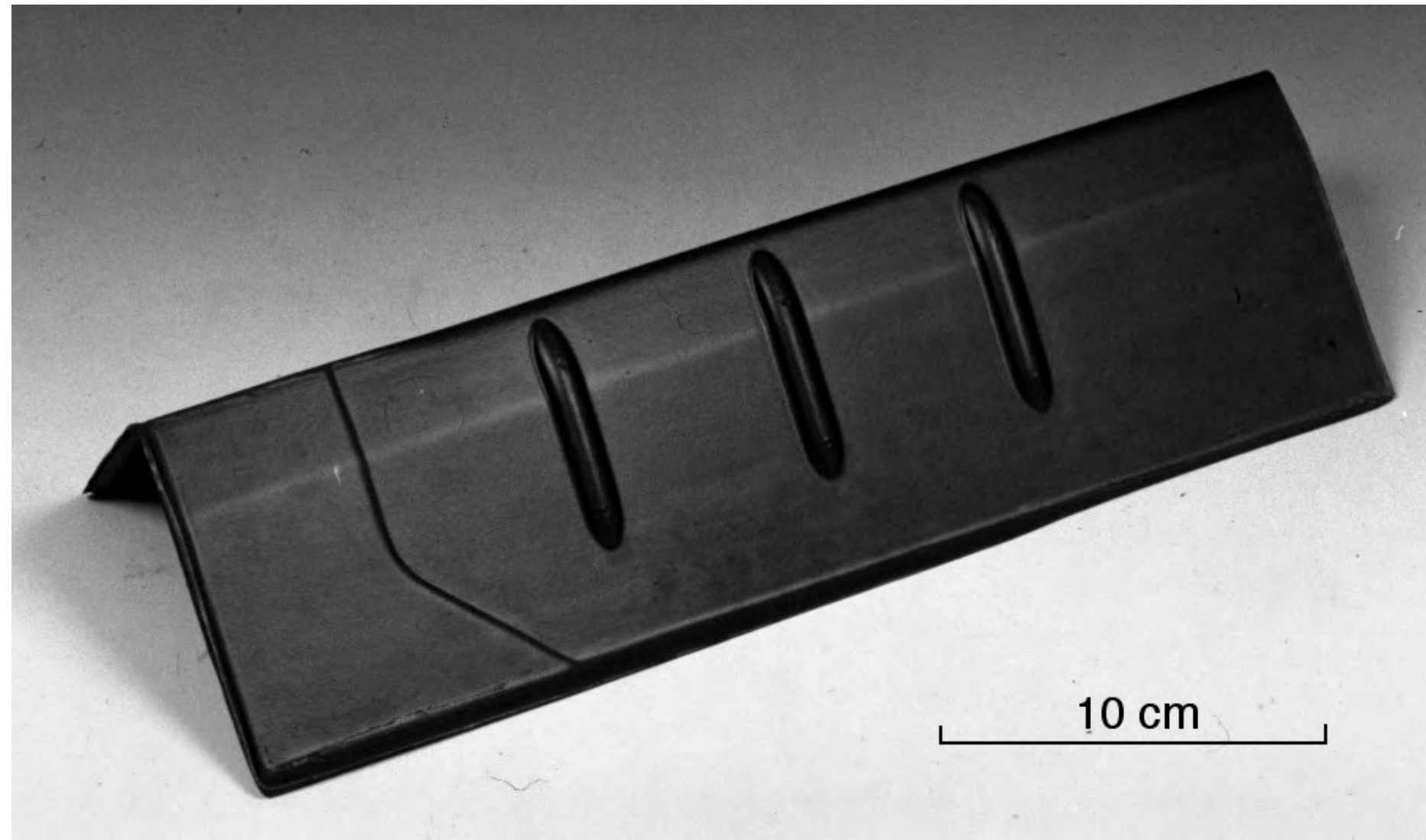
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JOURNAL



# Geopolymer-fiber-composites: heat and fire resistance





# “Geopolymer-based Composites”

Waltraud M. Kriven

Materials Science and Engineering, University of Illinois at Urbana-Champaign, USA

Vol. 5, *Ceramics and Carbon Matrix Composites*, edited by Marina Ruggles-Wrenn. Part of an 8 volume set of books entitled *Comprehensive Composite Materials II*, Peter Beaumont and Carl Zweben, Co-editors-in-chief. Published by Elsevier, Oxford, UK, in press (2017).

| Reinforcement   | Wt % Additions | Flexural strength (MPa) |
|---|----------------|-------------------------|
| <i>Abaca</i> (banana leaf fibers or “Manila hemp”) <sup>93</sup>  | 8              | 52                      |
| <i>Corn husk</i> fibers <sup>75</sup>   | 13             | 7.6 (7 % strain)        |
| Rice husk stems in rice husk silica-based GP <sup>80</sup>  | 7              | 12.4                    |
| <i>Jute</i> weave <sup>78</sup>   | 30             | 20.5                    |
| Colombian <i>fique/sisal</i> (unidirectional) <sup>79</sup>   | 50             | 11.4                    |
| Amazonian <i>malva</i> (unidirectional) <sup>95</sup>   | 5.5            | 31.55                   |
| Amazonian <i>curaua</i> (unidirectional) <sup>96</sup>  | 8.3            | 18.86                   |
| Amazonian <i>Guadua Angustifolia</i> chopped bamboo dispersed in Amazonian clay-based geopolymer <sup>84-87</sup> | 5              | 7.5                     |
| Bangladeshi <i>coconut coir</i> <sup>91</sup>   | 10             | 7.50                    |
| Bangladeshi <i>palm tree coir</i> <sup>91</sup>   | 10             | 7.61                    |



# State of the Geopolymer R&D 2017

1) Geopolymer science

2) Geopolymer technologies

**3) Geopolymer Cements / Concretes**

4) Geopolymer and archaeology





## The Rise and Rise of Geopolymer Concrete Researches Binds Us Together

Posted 10-04-2017

Category [Research](#)

[ASA](#) / [Blog](#) / [Research](#) / The Rise and Rise of Geopolymer Concrete Researches Binds Us Together

The exponential rise in geopolymer research is capturing industry interest. Published research papers covering geopolymer concrete, such as different mixes, methods and applications are challenging the conventional use of concrete. The association's involvement in the Cooperative Research Centre for Low Carbon Living research project is just one example of how much focus is being placed upon much geopolymer research.

As geopolymer concrete knowledge increases, so does its interest. The increasing amount of research, technical and commercial papers being produced and published supports this view. Geopolymer concrete is becoming more widely accepted within the industry and the promotion with reduced CO<sub>2</sub> benefits





**Australian Slag Association**

## **My recommendations to the Slag industrie:**

we have the same problems with slag GGBS

as with metakaolin MK-750:

Each slag tested reacts diferently



high increase

## University Consortium Prepares for Spike in Decommissioning

The Consortium for Decommissioning and Abandonment (CODA), a University of Texas at Austin is a response to the growing number of onshore and offshore wells, platforms and infrastructure that are approaching the end of economic viability and soon must be plugged and removed. Toward those ends, university researchers have developed several systems, including **geopolymer cements** .....





Tests of the newly designed cement also indicate significant self-healing properties. ...The system's designers are scheduled to present a paper (paper SPE 184675) on the geopolymers cement at the March SPE/IADC Drilling Conference in The Hague.

**SPE/IADC-184675-MS**

**True Self-Healing Geopolymer Cements for Improved Zonal Isolation and Well Abandonment**

Xiangyu Liu, Matthew J. Ramos, Sriramya D. Nair, Hanna Lee, D. Nicolas Espinoza, and Eric van Oort,  
The University of Texas at Austin





(19) **United States**

(12) **Patent Application Publication**  
**Allouche et al.**

(10) **Pub. No.: US 2017/0144933 A1**

(43) **Pub. Date: May 25, 2017**

---

(54) **GEOPOLYMER WITH NANOPARTICLE  
RETARDANT AND METHOD**

**Publication Classification**

(71) Applicant: **Louisiana Tech Research  
Corporation, Ruston, LA (US)**

(51) **Int. Cl.**  
*C04B 28/00* (2006.01)  
*C04B 40/06* (2006.01)  
*C04B 14/06* (2006.01)  
*C04B 22/06* (2006.01)

(57)

## **ABSTRACT**

A method of controlling the setting time of a geopolymer by coating aluminosilicate particles with nanoparticles to slow the geopolymerization reaction. The coating effectiveness of



[0039] Geopolymer paste samples 1A were prepared by premixing for approximately 30 seconds 20 grams of fly ash (e.g., Dolet Hills fly ash) with halloysite nanotubes in an amount that was 3% of the fly ash weight. The dry mixture

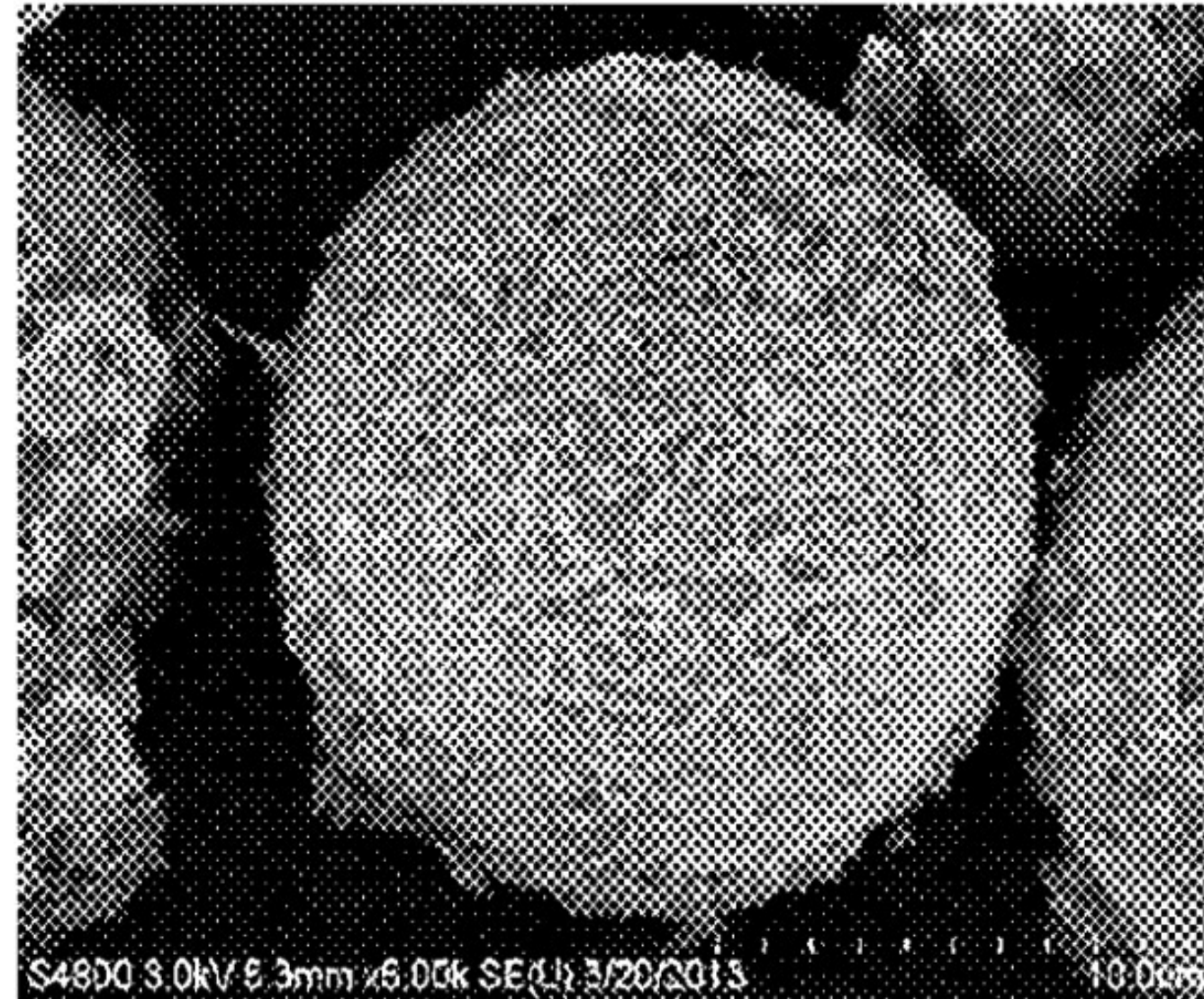


Fig. 2A

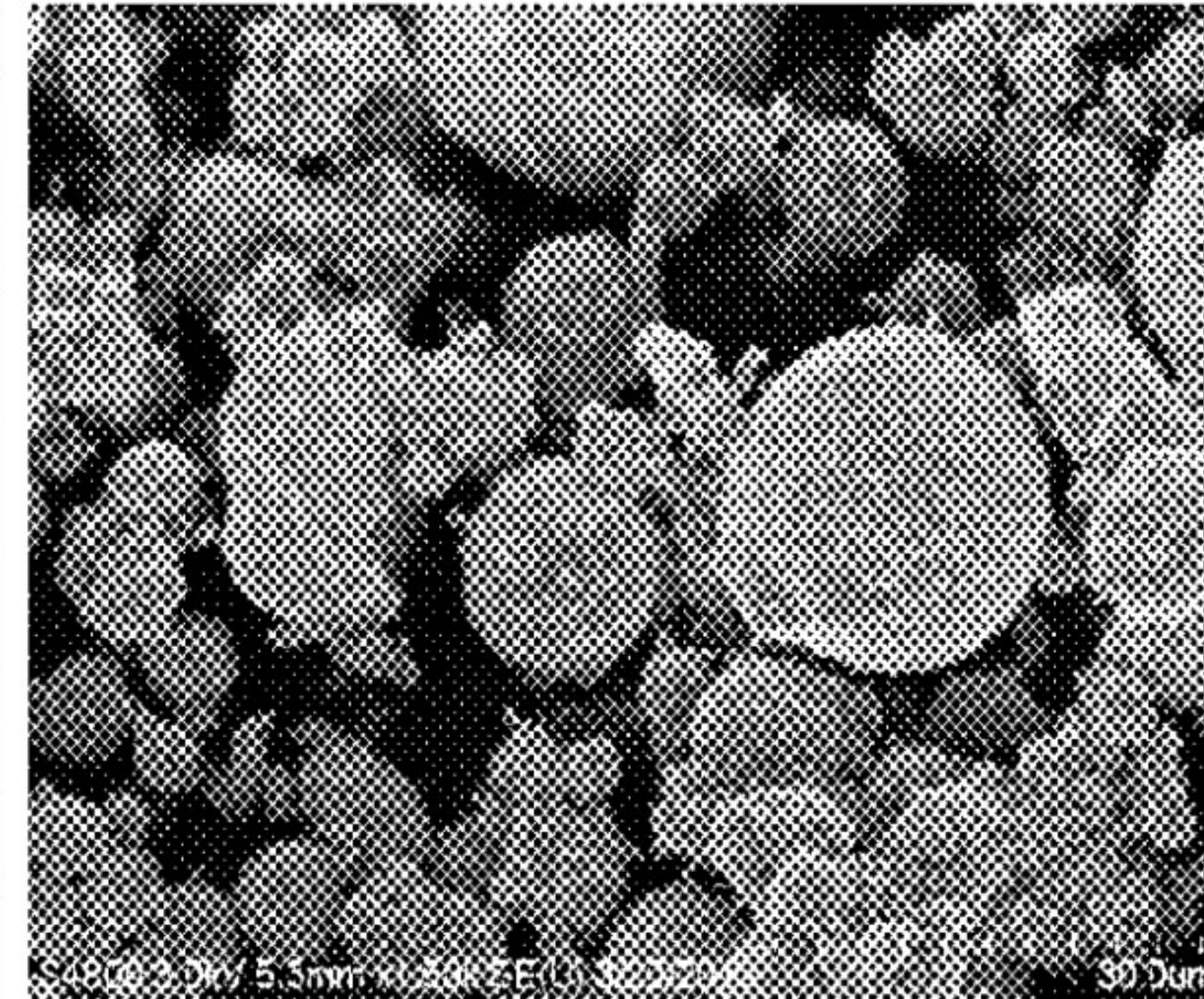


Fig. 2B



TABLE 3

|                            | Geopolymer<br>Paste<br>Control | Geopolymer<br>Paste 1A<br>(3% halloysite) | Geopolymer<br>Paste 1B<br>(6% halloysite) | Geopolymer<br>Paste 2A<br>(3% halloysite) | Geopolymer<br>Paste 2B<br>(6% halloysite) |
|----------------------------|--------------------------------|---|---|---|---|
| Initial<br>Setting<br>Time | 18 min.<br>24 sec              | 70 min<br>35 sec                          | 175 min                                   | 47 min<br>55 sec                          | 117 min                                   |
| Final<br>Setting<br>Time   | 25 min<br>43 sec               | 85 min<br>45 sec                          | 205 min                                   | 49 min<br>49 sec                          | 147 min                                   |

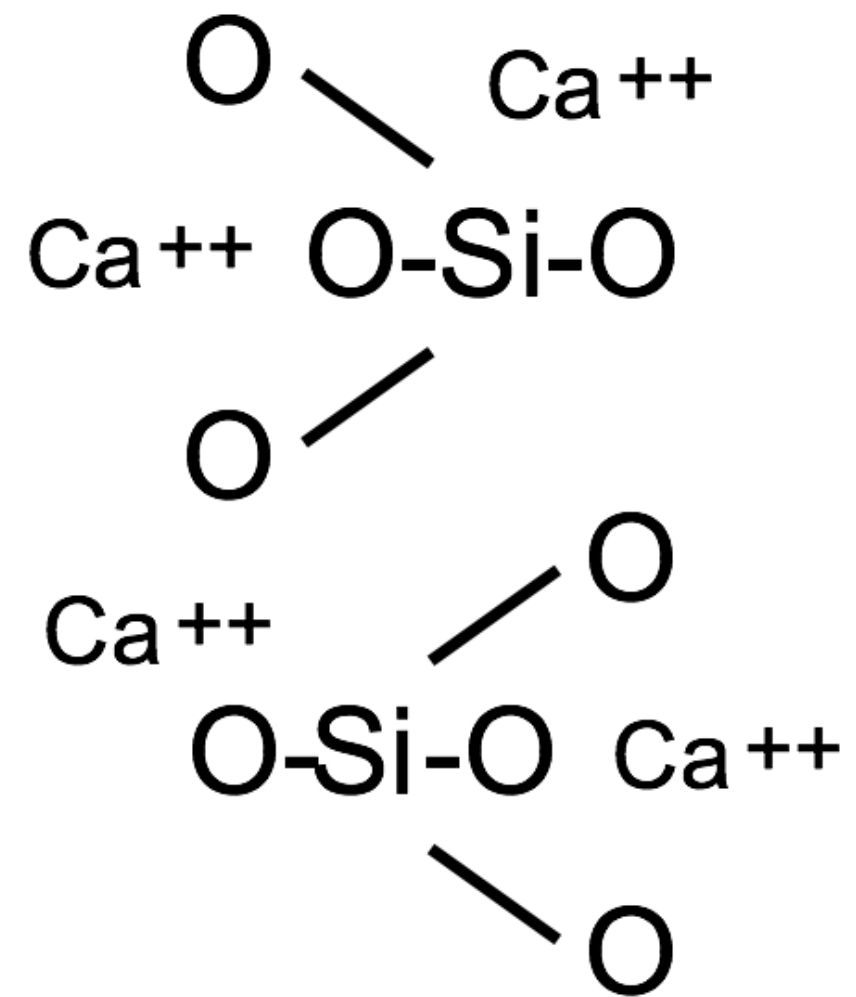
**Only  
valid for  
class C  
fly ashes**

[0039] Geopolymer paste samples 1A were prepared by premixing for approximately 30 seconds 20 grams of fly ash (e.g., Dolet Hills fly ash) with halloysite nanotubes in an amount that was 3% of the fly ash weight. The dry mixture

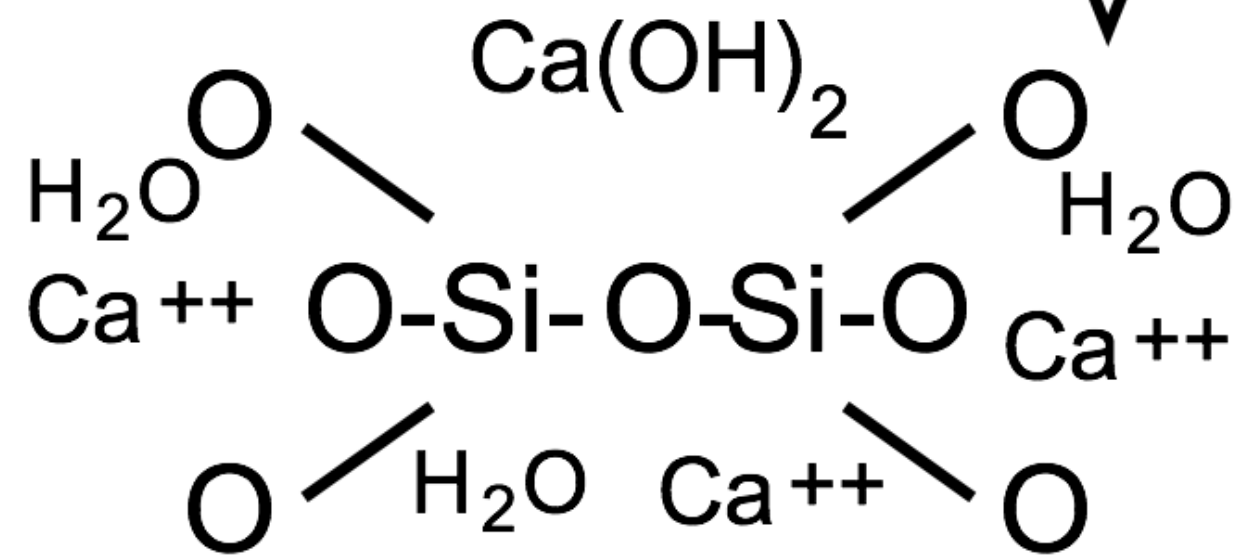


Last words on  
**AAM** alkali-activated materials  
vs  
Geopolymer cement





Portland  
Cement

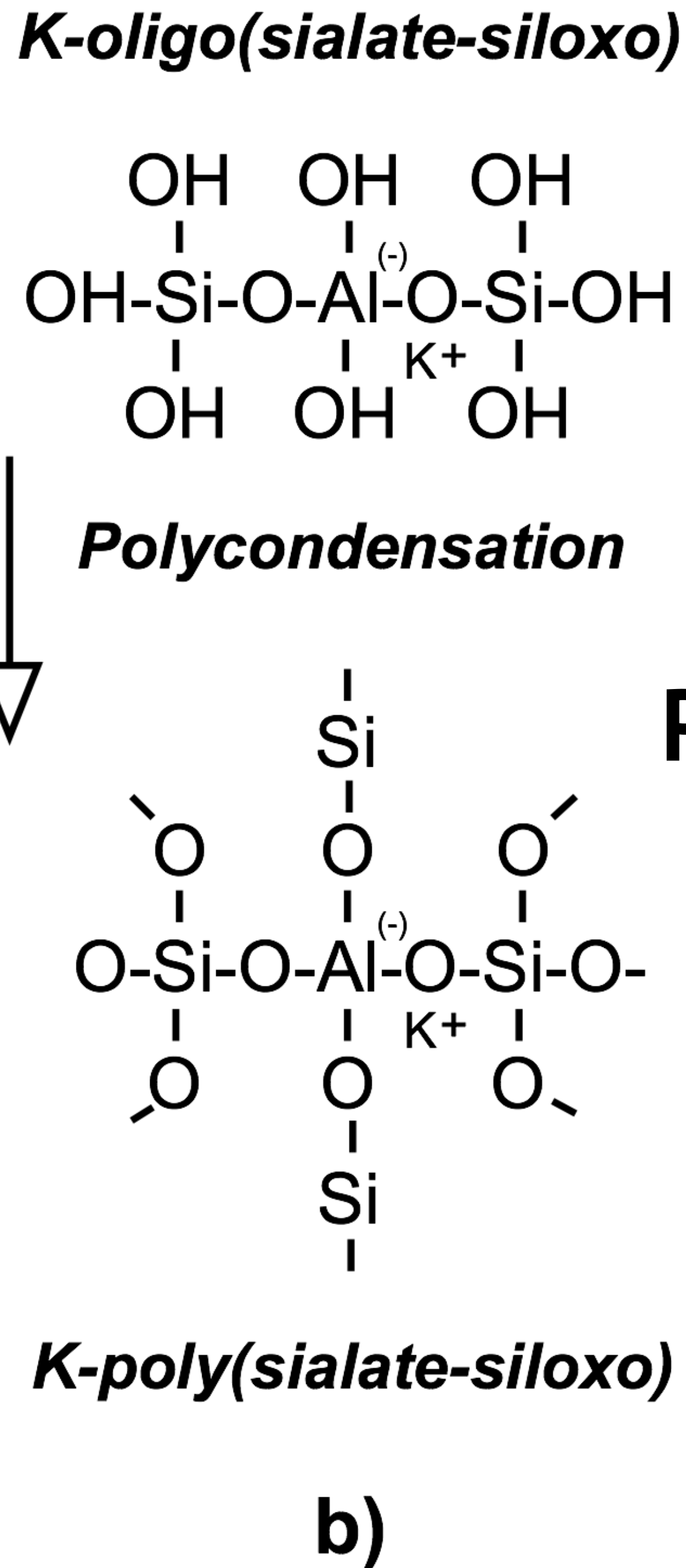
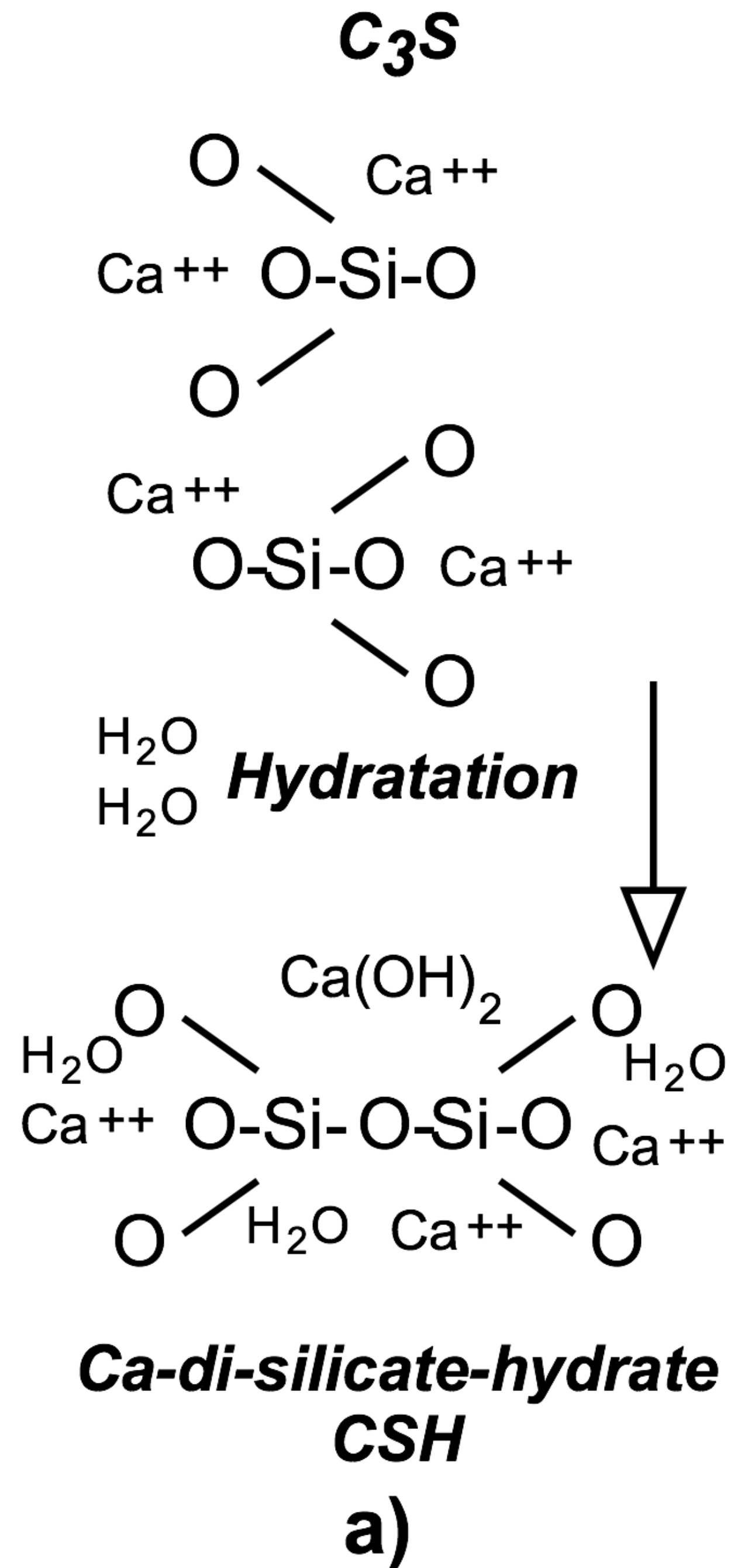


**Ca-di-silicate-hydrate**  
**CSH**

**a)**



Portland  
Cement



Geopolymer is a  
**Polymer Chemistry**  
*(poly-sialate)*



## **Portland cement**

$\text{CaO} \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$  Calcium Silicate Hydrate

C-S-H

Alkali-activated-materials scientists

substitution of Ca with Na, K

## **Geopolymer**

$\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot \text{H}_2\text{O}$  Sodium-Alumino-Silicate-Hydrate

N-A-S-H

$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot \text{H}_2\text{O}$  Potassium-Alumino-Silicate-Hydrate

K-A-S-H



**According to AAM specialists from RILEM**

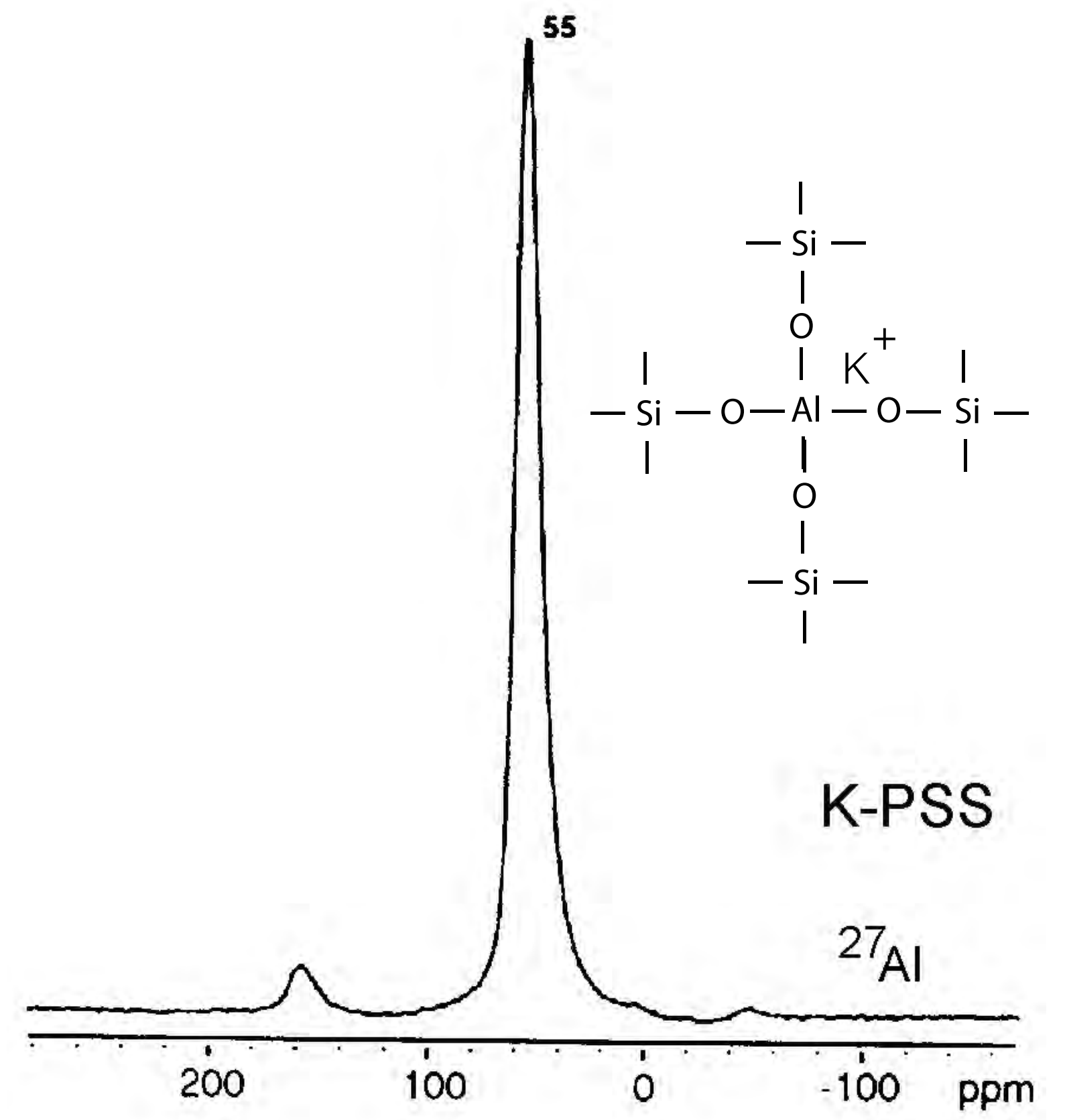
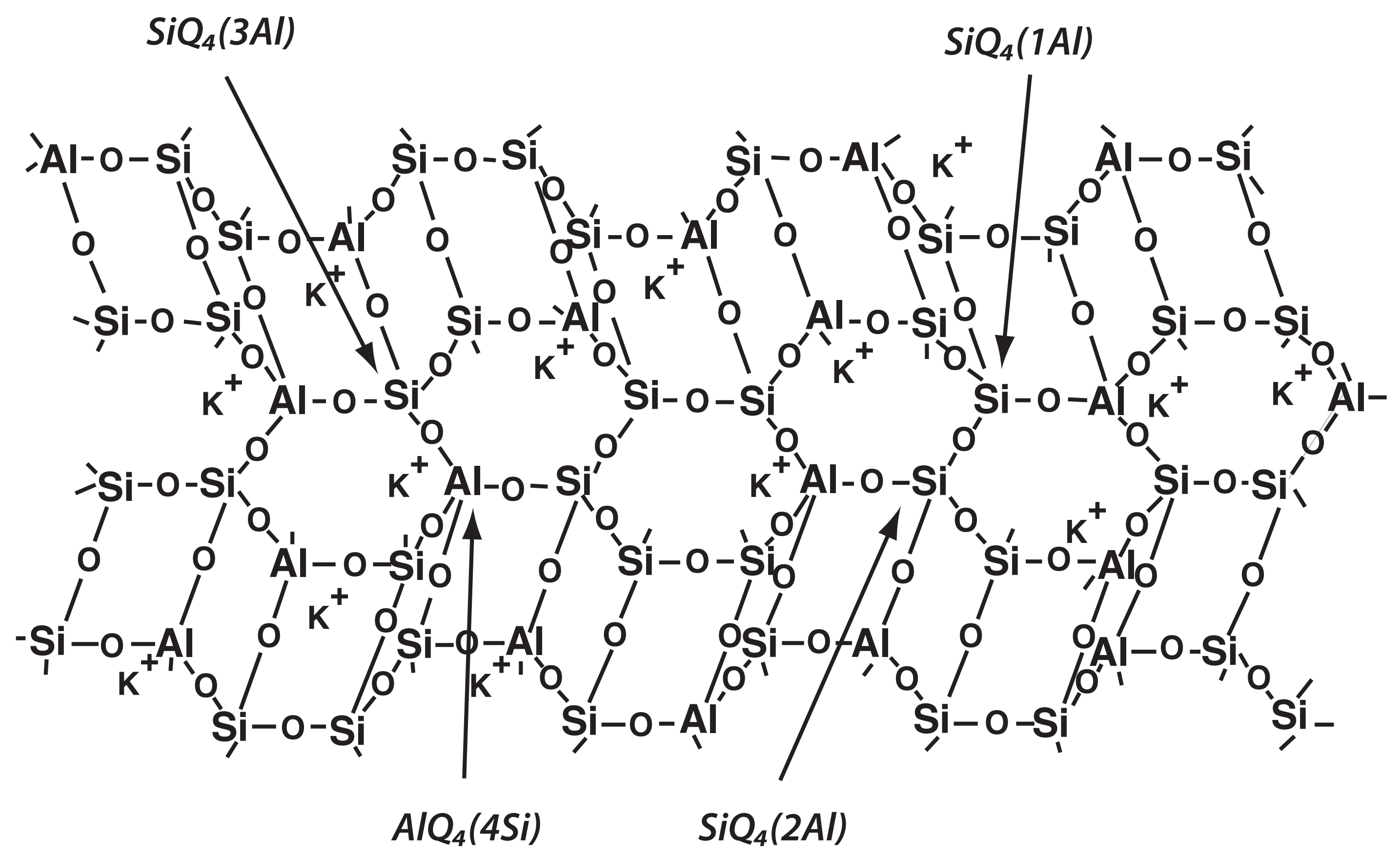
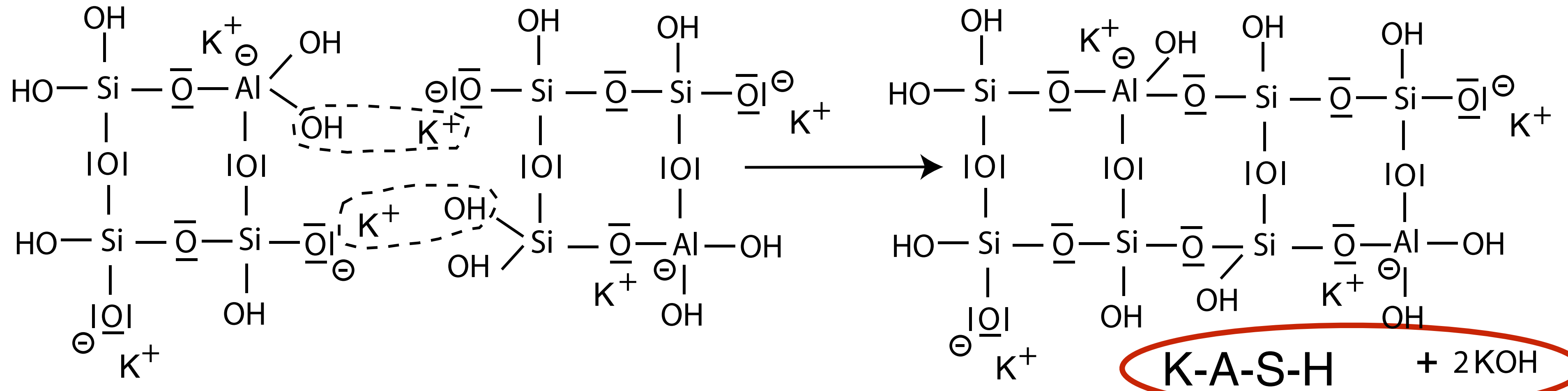
**“GEOPOLYMER” is a type of  
alkali-alumina-HYDRATE, a precipitate,**

**N-A-S-H, K-A-S-H**

**Nothing else !!!**

**WRONG**







(12) **United States Patent**  
Skorina et al.

(10) **Patent No.:** **US 9,340,465 B2**  
(45) **Date of Patent:** **May 17, 2016**

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(54) **ALKALI METAL ION SOURCE WITH  
MODERATE RATE OF ION RELEASE AND  
METHODS OF FORMING**

(56) **References Cited**  
U.S. PATENT DOCUMENTS

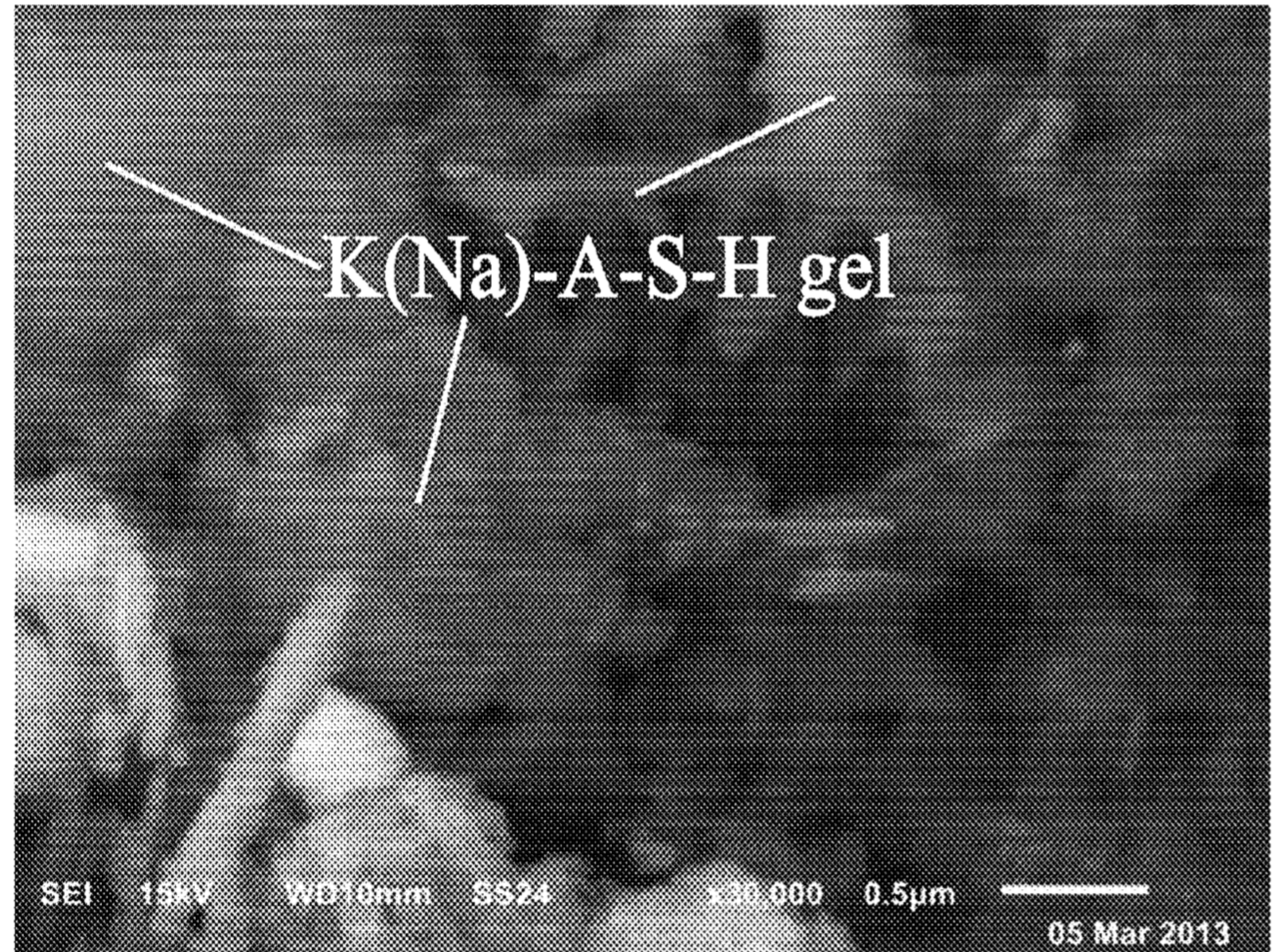
There is a growing need for alternative sources of alkali metals, such as, but not limited to, potassium ... (traditional potassium fertilizing agent) ... making local manufacturing of potassium fertilizer increasingly attractive....

Therefore, a need exists to produce a source of potassium ion that **releases the nutrient (K cation) at a moderate rate**, lower than the infinite dissolution rate of a traditional salts, but faster than the rate generally exhibited by naturally-occurring minerals.



Claim: ...The method wherein the weight percent of K(Na)-A-S-H gel of the alkali metal ion source is between about 10% and about 100%.

Applicant: Massachusetts Institute of Technology M.I.T., Cambridge, Boston.





# **N-A-S-H**

Sodium Aluminosilicate

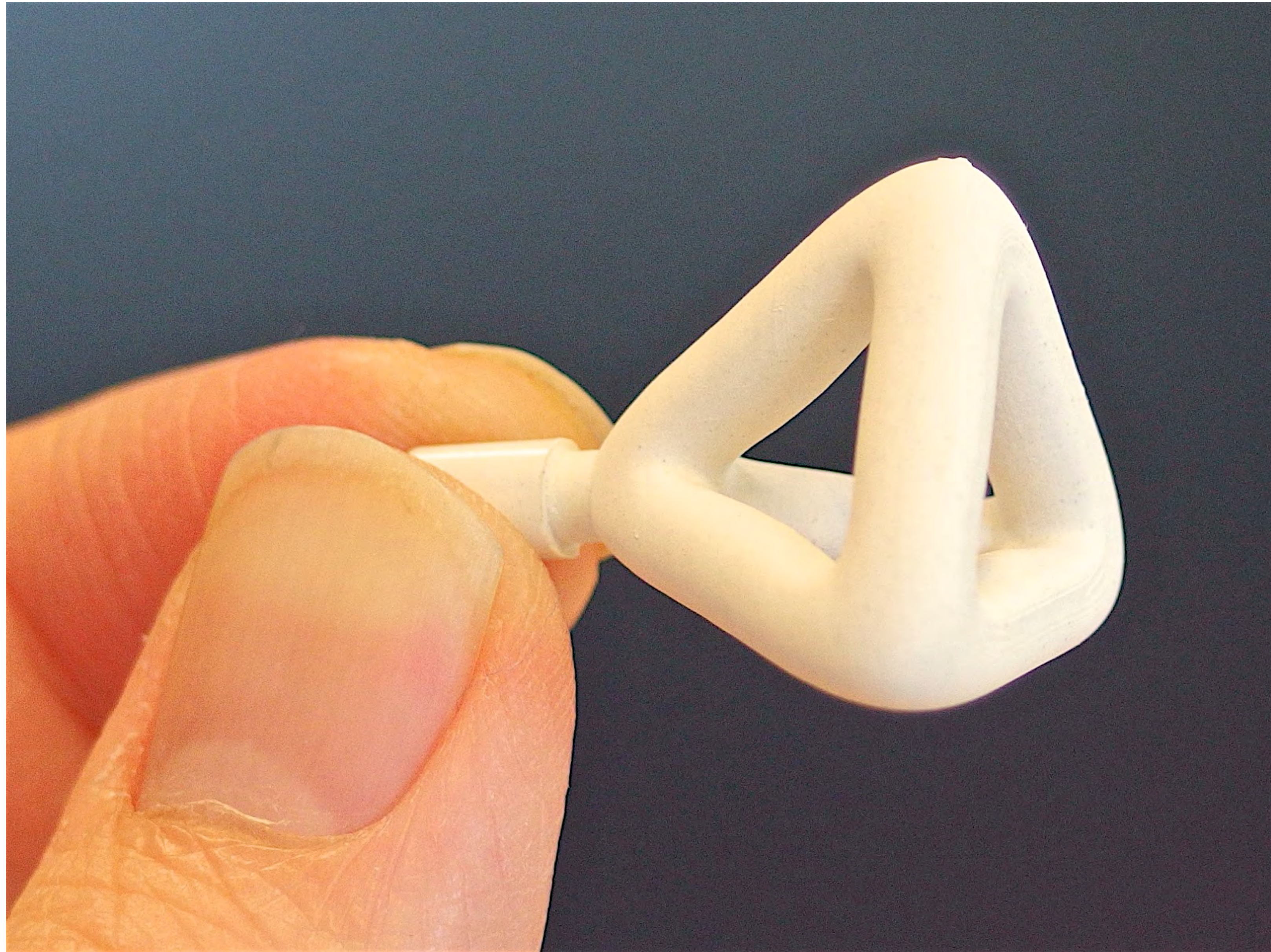
Hydrate

Alkali-Activated Materials



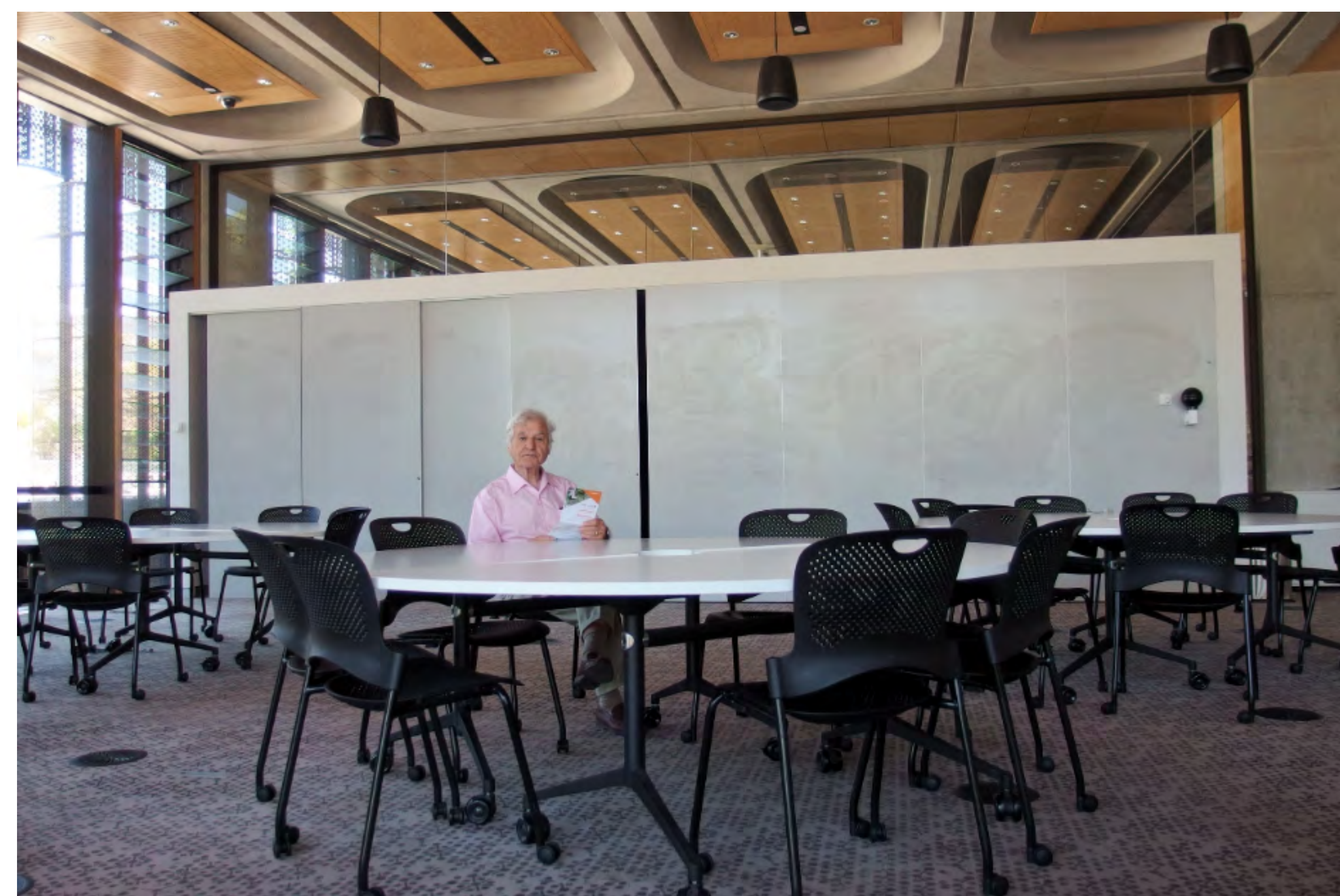


***Poly(sialate-siloxo)  
geopolymer  
ceramic***





# *Poly(sialate-siloxo) geopolymer concrete*



**Global Change Institute, Univ. Queensland, Brisbane, Australia**



# Toowoomba-Brisbane-West Wellcamp Airport, by WAGNERS, Australia

October 2015



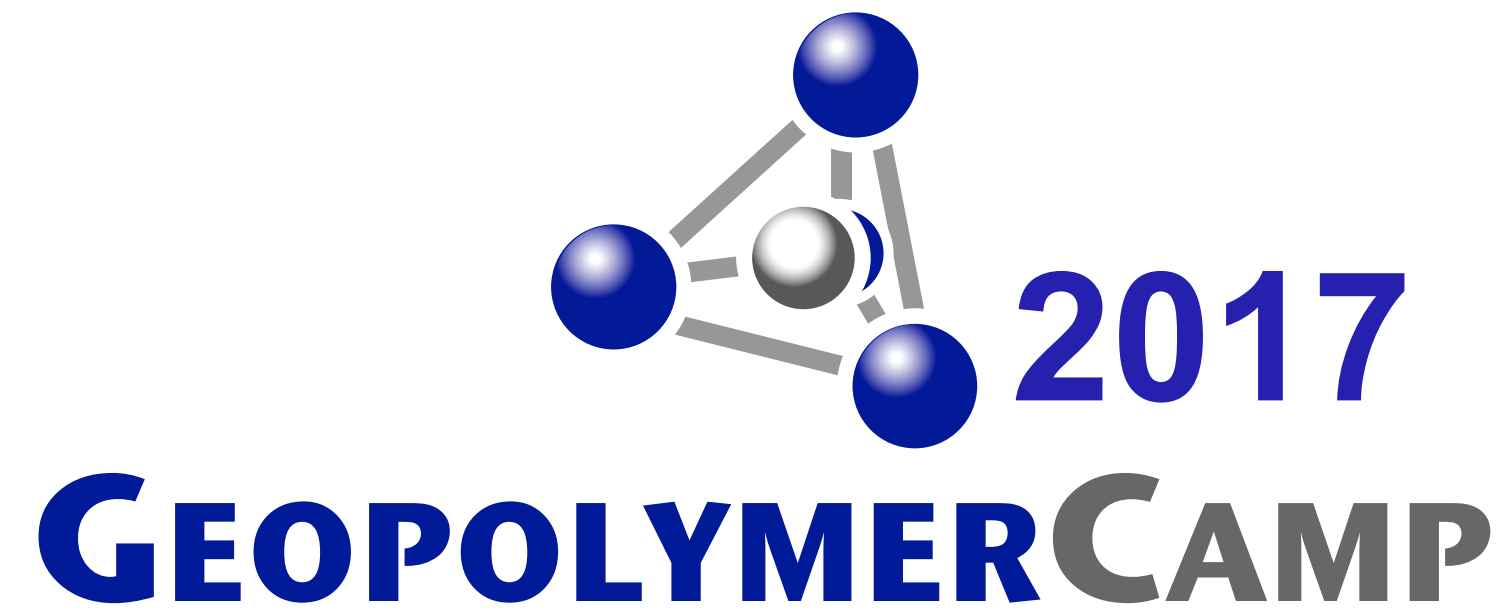
**100,000 tonnes  
Slag/fly ash-based geopolymer concrete EFC (Earth Friendly  
Concrete)**



# State of the Geopolymer R&D 2017

- 1) Geopolymer science
- 2) Geopolymer technologies
- 3) Geopolymer Cements / Concretes
- 4) Geopolymer and archaeology**





Tuesday, July 11, 2017

## **Third session: Geopolymer and archaeology**

Ancient Roman concrete (100 BC): rapid setting



*11th International Congress of Egyptologists,  
Florence, Italy, 23-30 August, 2015*



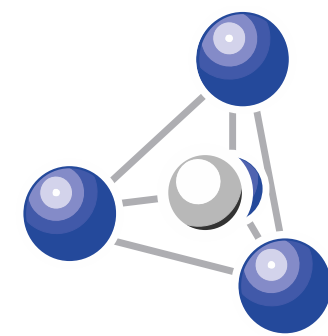
*Joseph Davidovits*

*Frédéric Davidovits*

Non-destructive analysis on 11 Egyptian blue  
faience tiles from the 2nd and 3rd Dynasties.

*(accepted for publication in the Proceedings)*





INSTITUT  
**GÉOPOLYMÈRE**

**02100 Saint-Quentin, France**

[www.geopolymer.org](http://www.geopolymer.org)



Joseph Davidovits

Ralph Davidovits



DEPARTMENT OF  
MATERIALS SCIENCE  
AND ENGINEERING

*October 4, 2016*

***Non-destructive analysis on 11 Egyptian blue faience tiles from the 2nd and 3rd Dynasties (2650 BC).***



Zoser Step Pyramid

Saqqarah

3rd Dynasty

2700 BC

35,000 faience tiles  
in subterranean galleries







efflorescence self-glazing process:  
migration of alkali salts and  $\text{CuO}$   
then firing at  $800\text{-}850^{\circ}\text{C}$   
turquoise-blue glaze







# **Why Djoser's blue Egyptian faience tiles are not blue?**

## **Manufacturing Djoser's faience tiles at temperatures as low as 250°C?**

***Joseph Davidovits***

*Institut Géopolymère, 02100 Saint-Quentin, France*

***Ralph Davidovits***

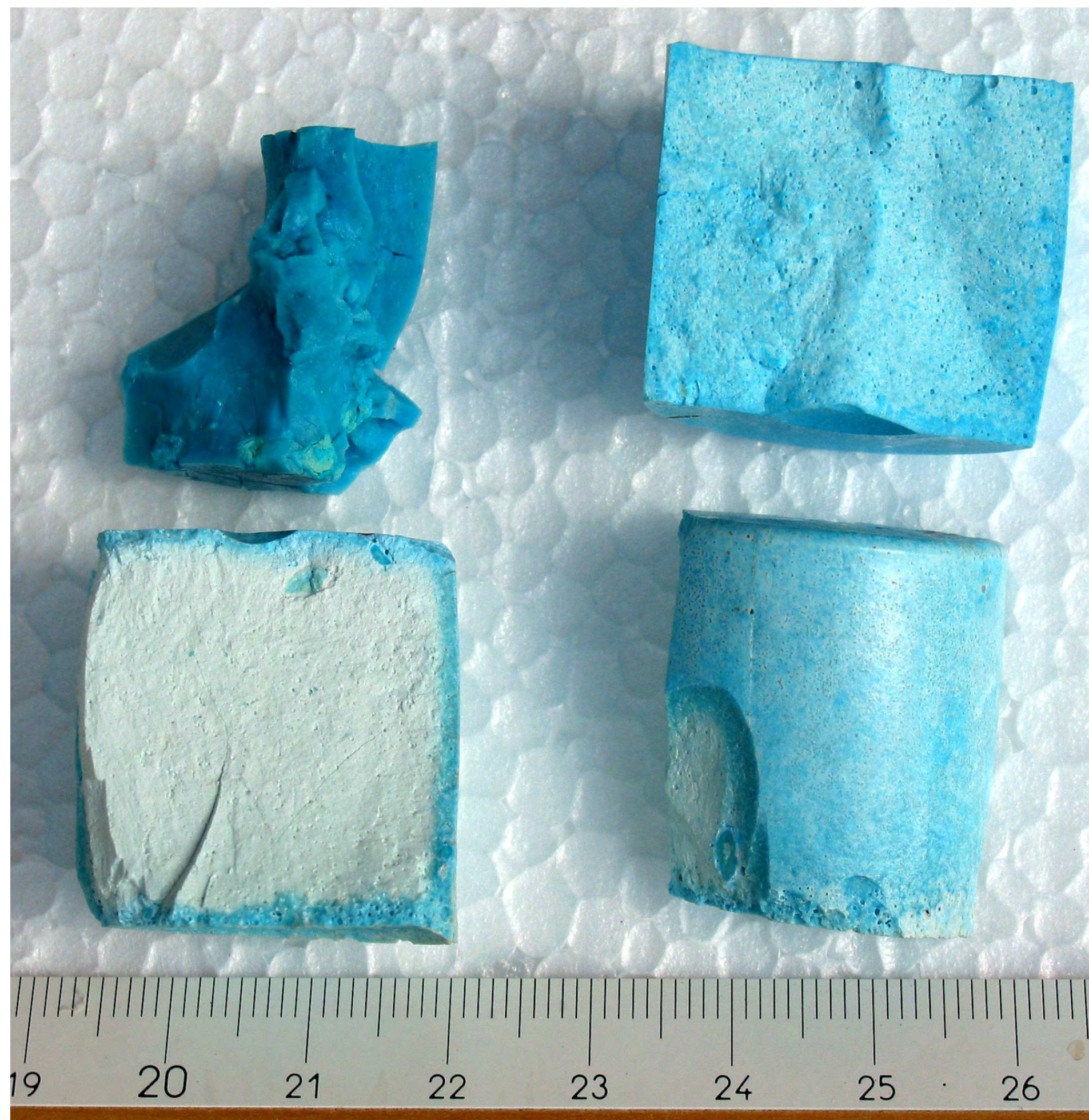
*Cordi-Géopolymère SA*

*Laboratoire de Recherche sur les Nouveaux Matériaux*

*02100 Saint-Quentin*



To replicate the self-glazing process with soluble silicate  
 $\text{SiO}_2, \text{K}_2\text{O}, \text{Na}_2\text{O}$  + synthetic turquoise (*mafkat*):  
aluminium phosphate hydrate + copper phosphate hydrate  
at 250°C.





Lucien Viola,  
Galerie l'Ibis,  
Marrakech

Thermoluminescence analysis for datation:  
ceramics that are fired at  $t^{\circ} > 500^{\circ}\text{C}$



OXFORD AUTHENTICATION Ltd

Boston House  
Grove Technology Park  
Wantage  
Oxfordshire OX12 9FF  
England

Tel: +44 (0)1235 770998  
Fax: +44 (0)1235 771021  
Email: info@oxfordauthentication.com  
Website: www.oxfordauthentication.com

Sample No: N109p38

#### THERMOLUMINESCENCE ANALYSIS REPORT

The object was presumed to be:  
A turquoise faience tablet

The following samples were taken in powder form on: 24 October 2009  
By: Helen Mason of Oxford Authentication Ltd

Sample A: Into break on side

Result: It is not possible to issue a result for this piece as the sample is too low-fired and lacks radioactive inclusions. We are therefore unable to complete our analysis and draw any conclusions regarding its age.

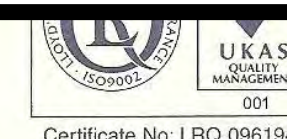
Date: 14 November 2009

Signature:

Helen Mason for Oxford Authentication Ltd

Oxford Authentication takes no responsibility for financial loss incurred if results were obtained. If the object has suffered restoration the date may be different from the date of manufacture if the object has not been exposed to ionising radiation. The date of analysis will be that of the original firing and not the date of re-

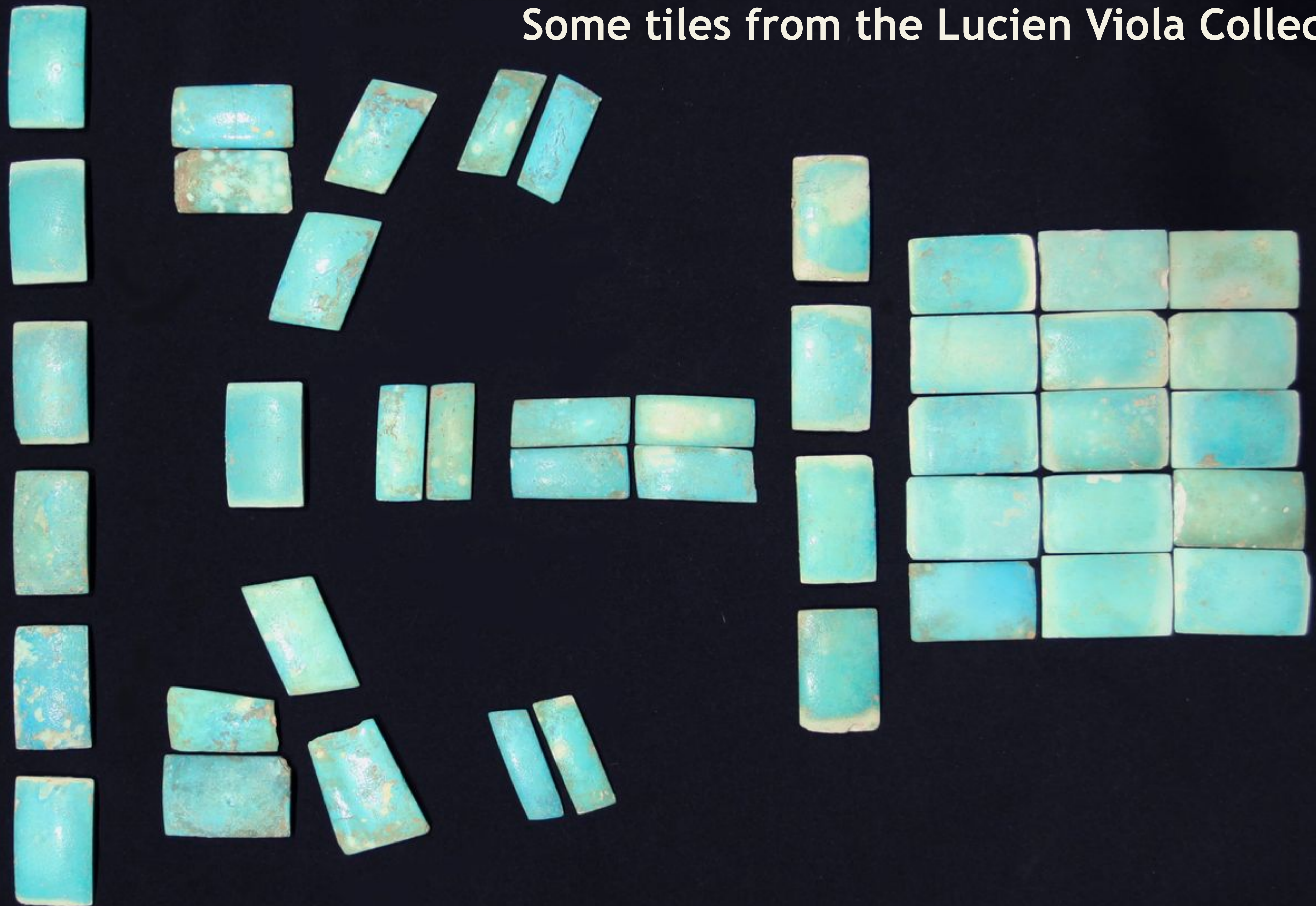
**RESULT: It is not possible to issue a result for this piece as the sample is too low-fired and lacks radioactive inclusions. We are therefore unable to complete our analysis and draw any conclusions regarding its age.**



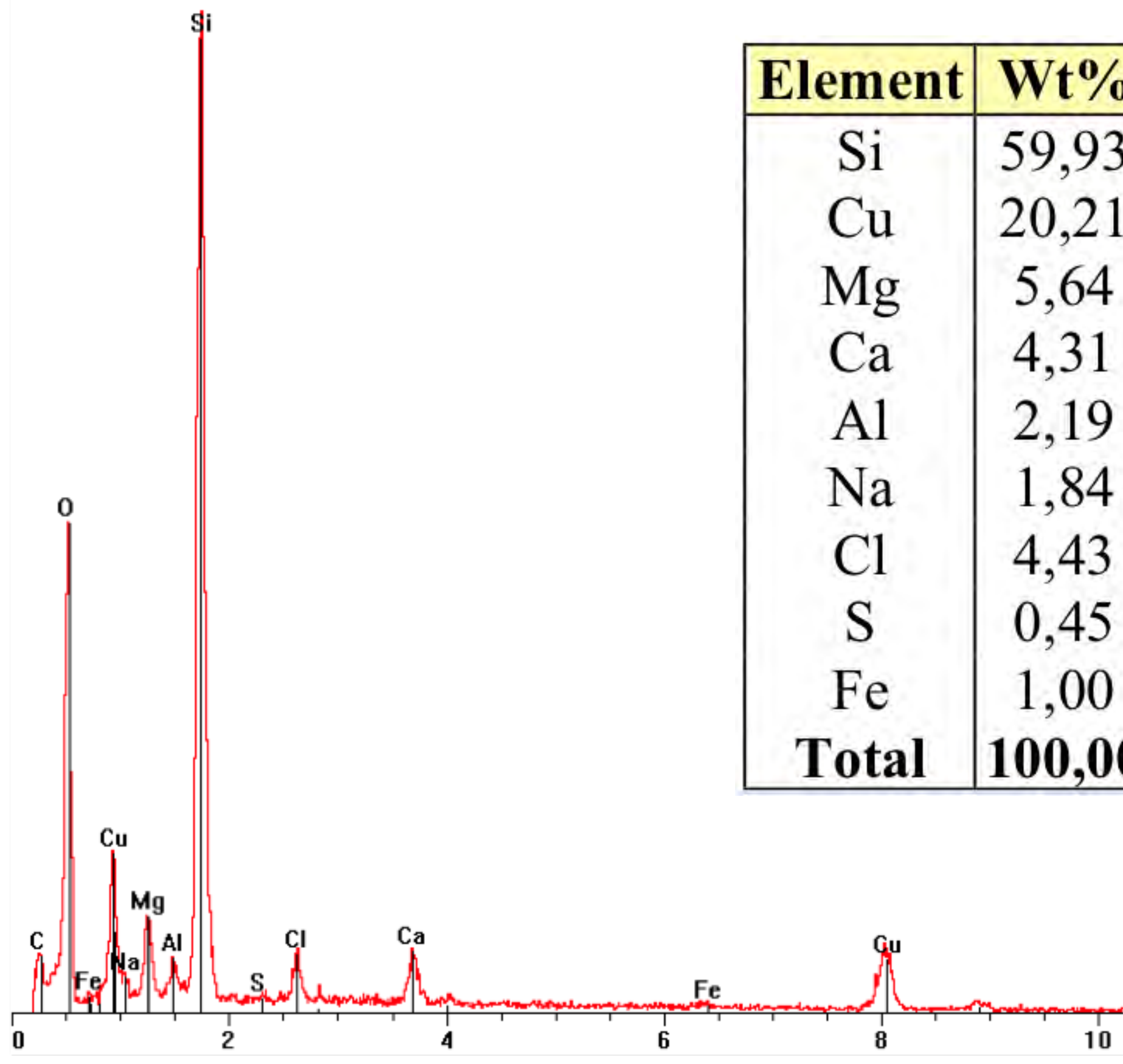
Registered in England, no. 3331225 Registered Office: 14 Bridge End, Dorchester-on-Thames, Oxfordshire OX10 7JP



# Some tiles from the Lucien Viola Collection







| Element      | Wt%           | At%           |
|--------------|---------------|---------------|
| Si           | 59,93         | 68,63         |
| Cu           | 20,21         | 10,23         |
| Mg           | 5,64          | 7,46          |
| Ca           | 4,31          | 3,46          |
| Al           | 2,19          | 2,61          |
| Na           | 1,84          | 2,57          |
| Cl           | 4,43          | 4,02          |
| S            | 0,45          | 0,45          |
| Fe           | 1,00          | 0,58          |
| <b>Total</b> | <b>100,00</b> | <b>100,00</b> |

$\text{Cu}_2\text{Cl}(\text{OH})_3$   
 $(\text{Mg}, \text{Ca})\text{CuSi}_4\text{O}_{10}$   
 Atacamite  
 Egyptian Blue





Nr. 4



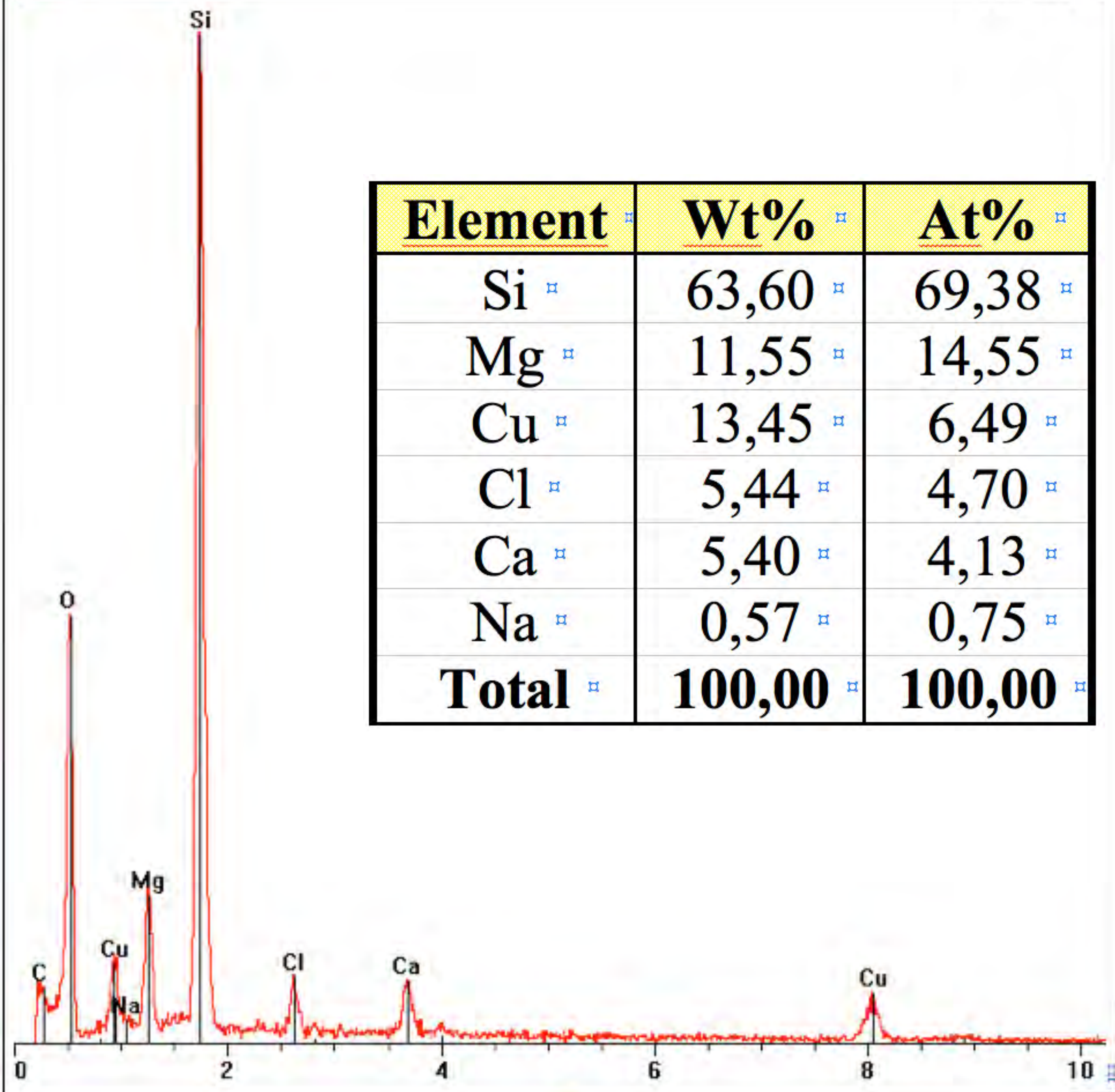


Glaze

Magn 250x Det BSE WD 10.1 1.2 Torr | 100 μm

2-surface-.pgt

FS: 1200



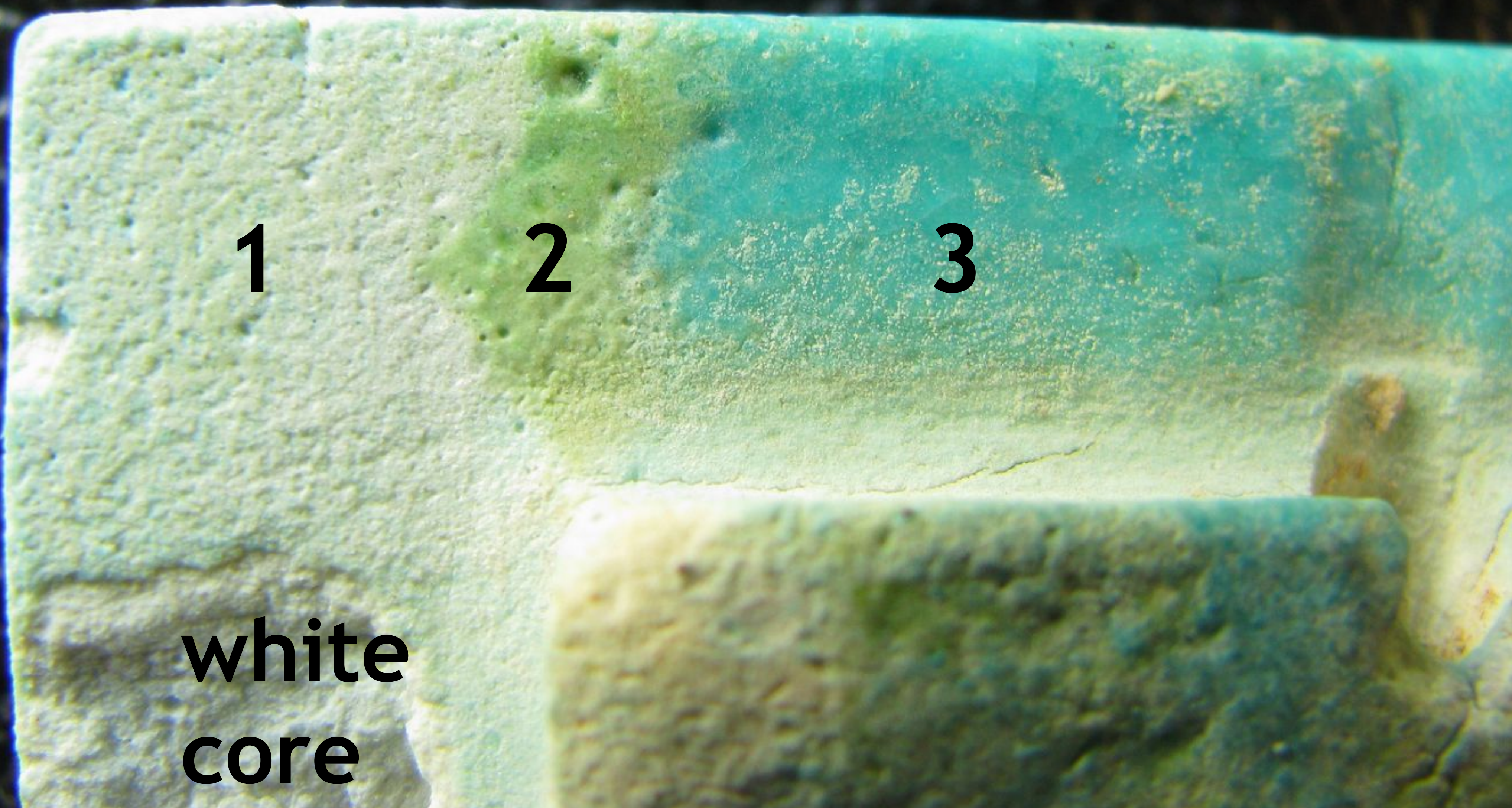
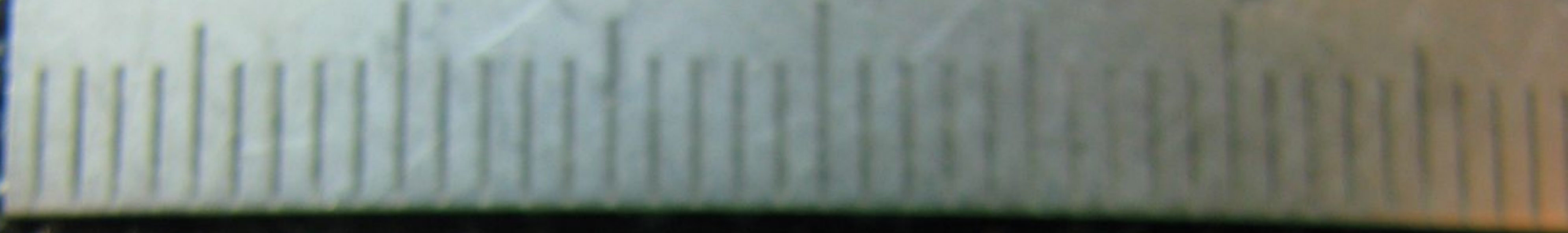
| Element      | Wt%           | At%           |
|--------------|---------------|---------------|
| Si           | 63,60         | 69,38         |
| Mg           | 11,55         | 14,55         |
| Cu           | 13,45         | 6,49          |
| Cl           | 5,44          | 4,70          |
| Ca           | 5,40          | 4,13          |
| Na           | 0,57          | 0,75          |
| <b>Total</b> | <b>100,00</b> | <b>100,00</b> |



Nr. 4







**1**

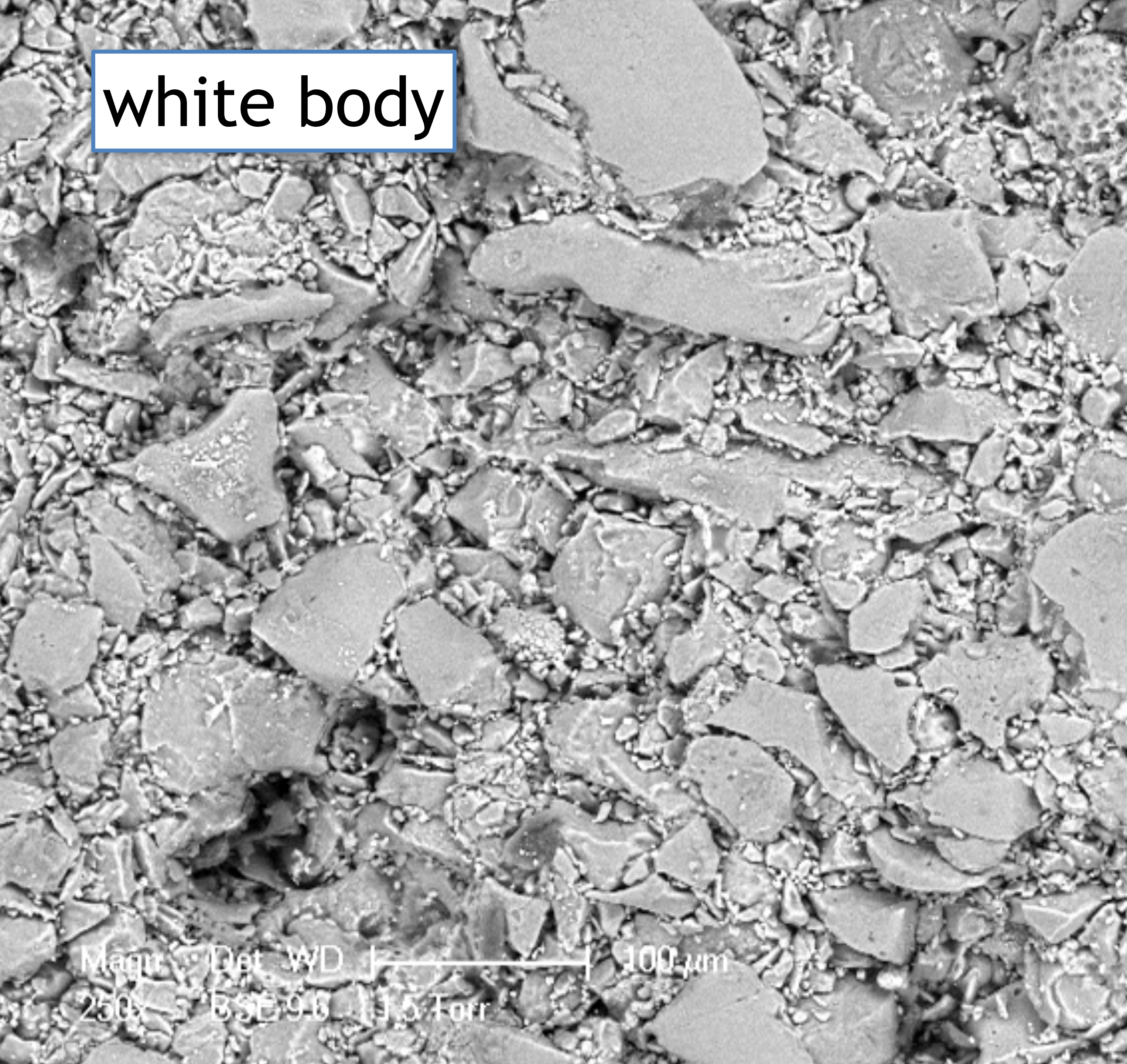
**2**

**3**

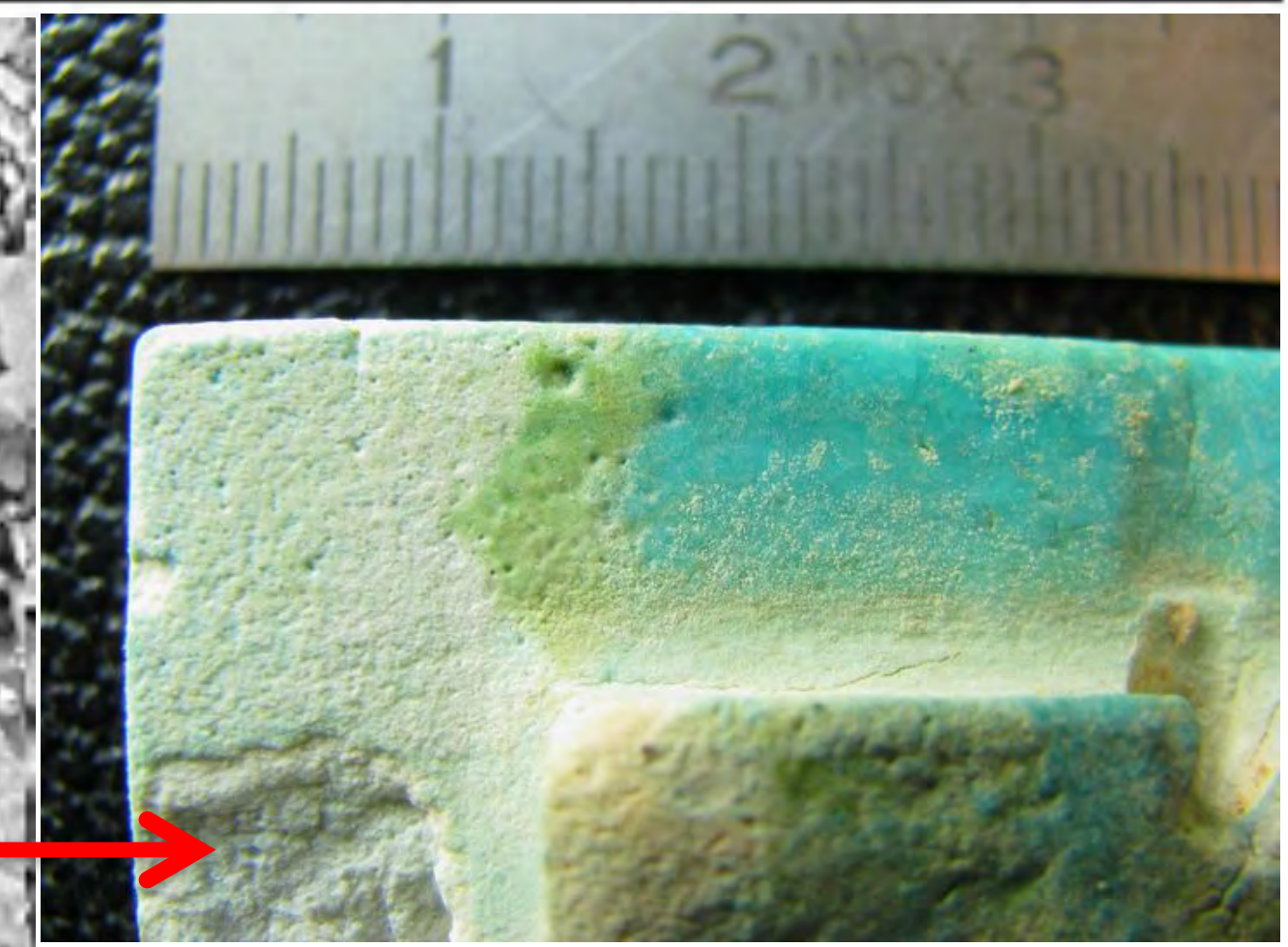
**white  
core**



white body

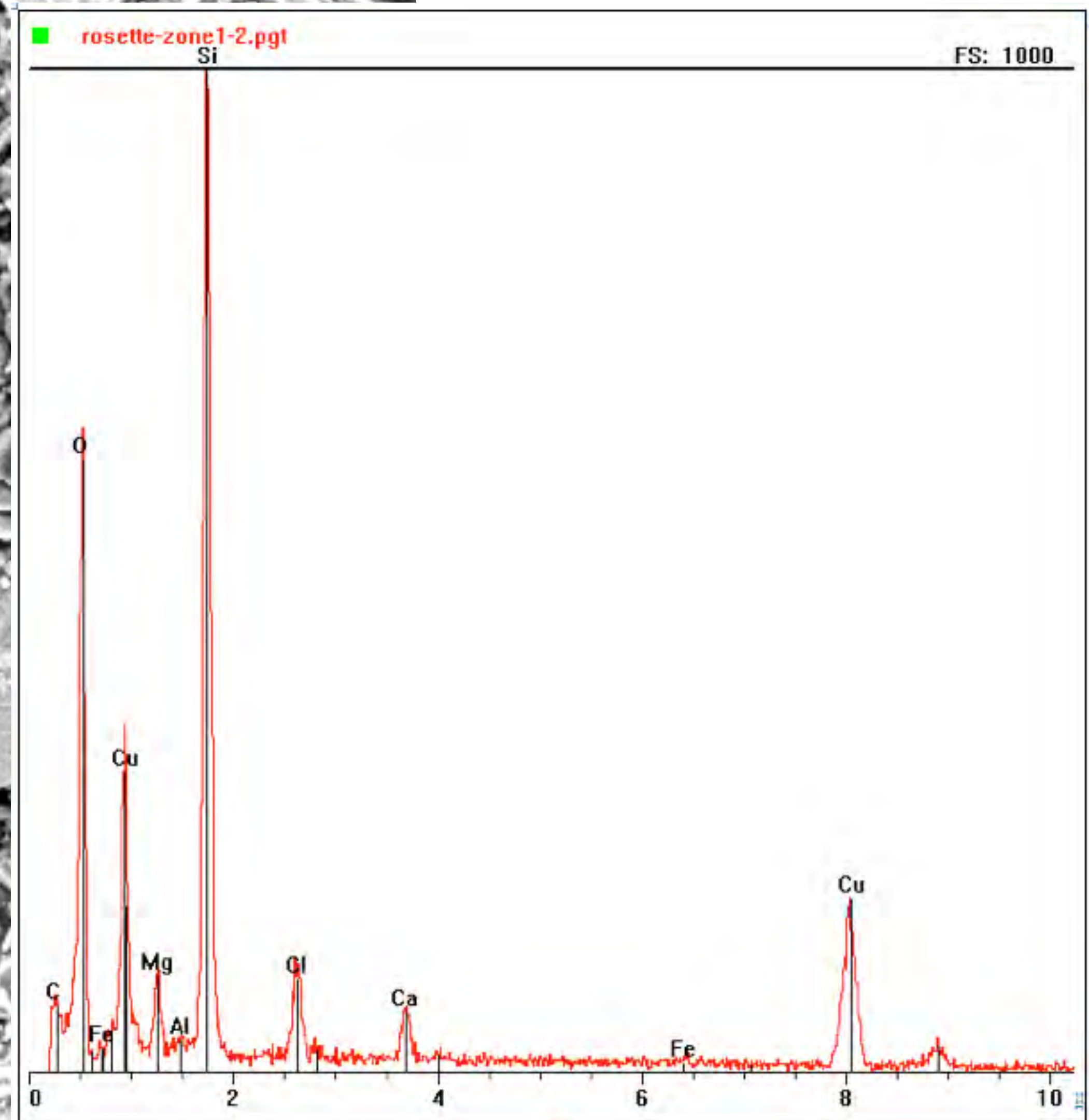
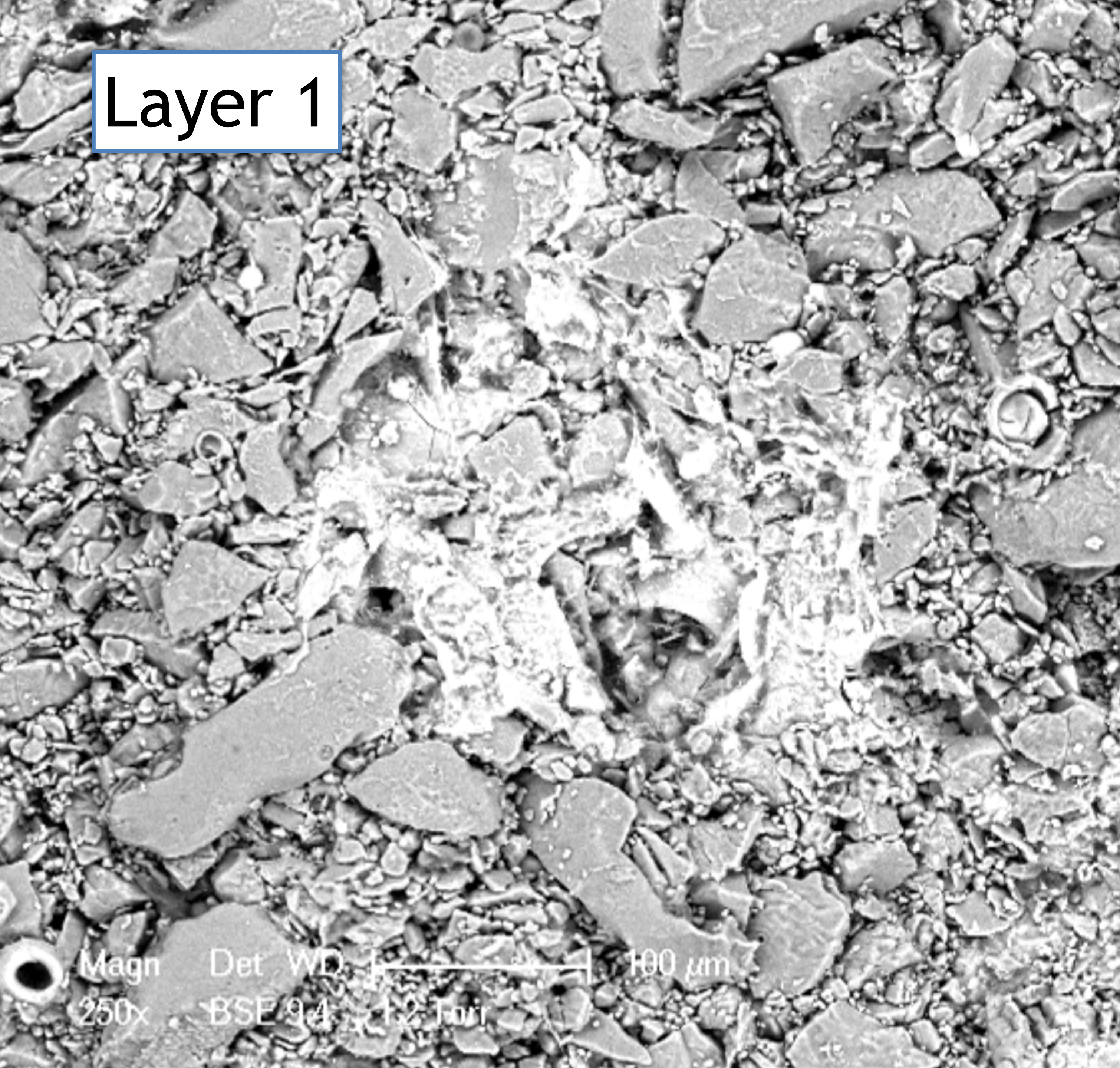


| Element      | Wt%           | At%           |
|--------------|---------------|---------------|
| Ca           | 1,90          | 1,40          |
| Cu           | 7,69          | 3,58          |
| Si           | 82,27         | 86,59         |
| Cl           | 2,53          | 2,11          |
| K            | 1,08          | 0,82          |
| Mg           | 1,86          | 2,26          |
| Na           | 1,66          | 2,14          |
| Al           | 1,01          | 1,11          |
| <b>Total</b> | <b>100,00</b> | <b>100,00</b> |





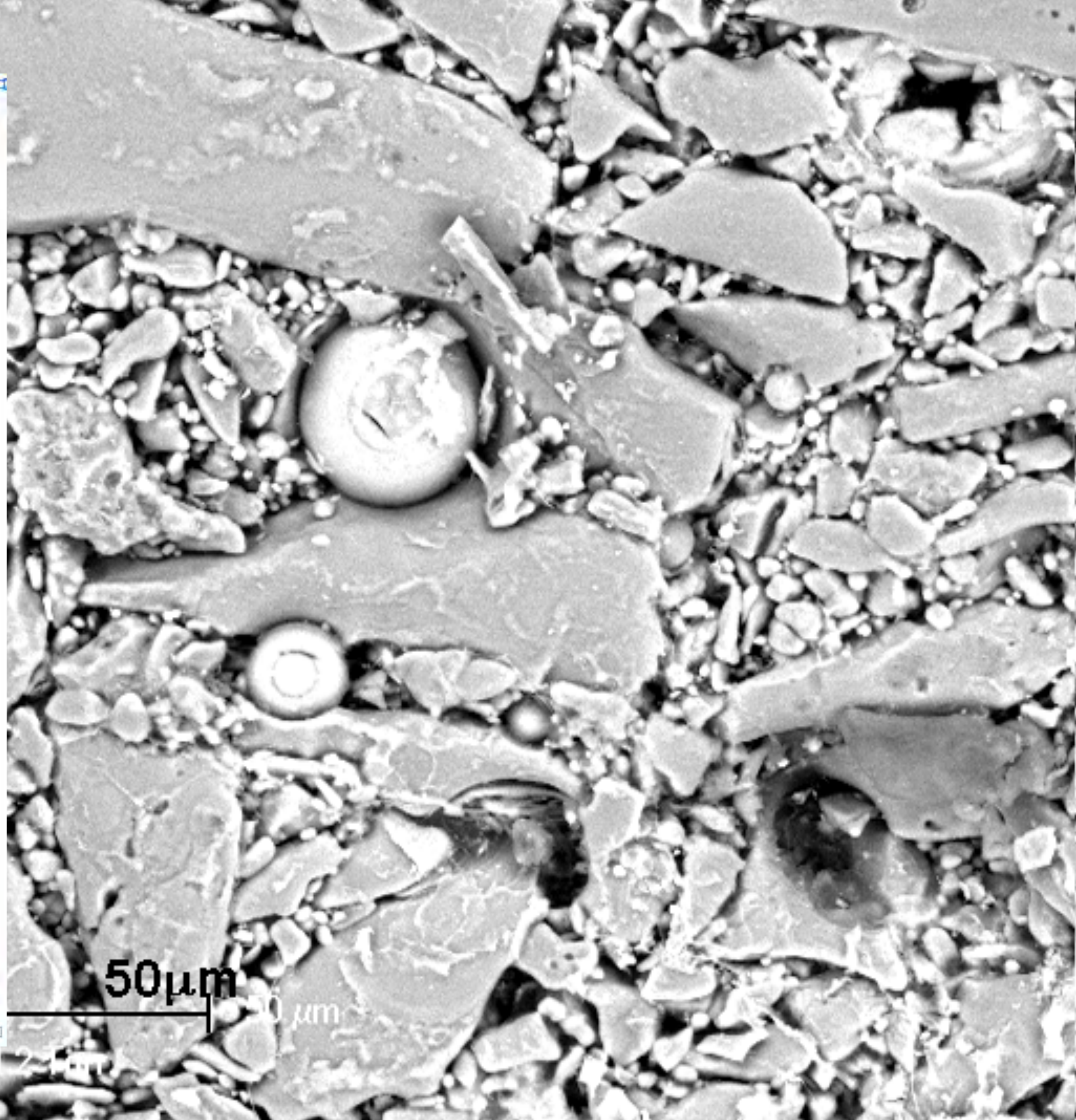
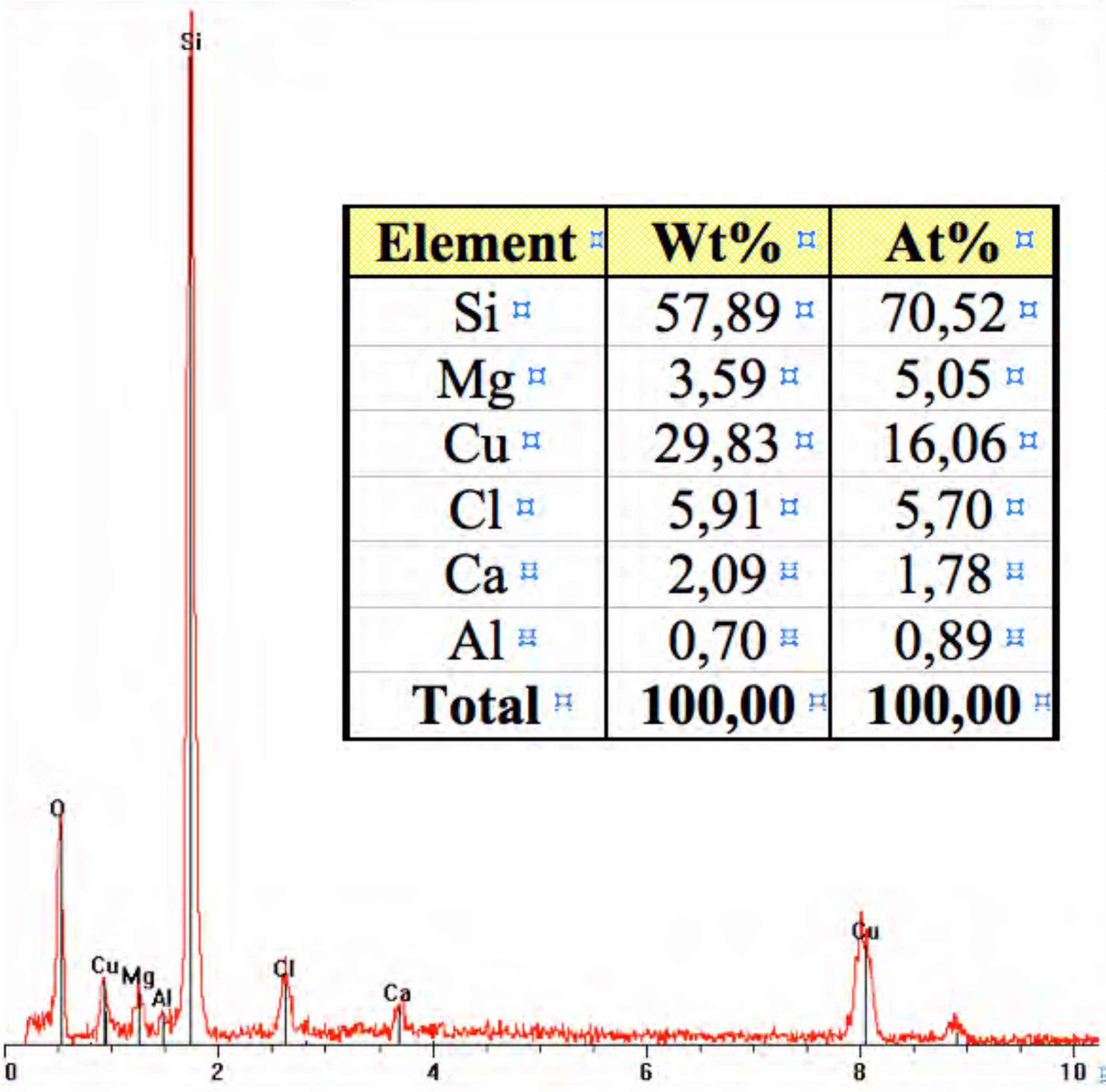
Layer 1



1



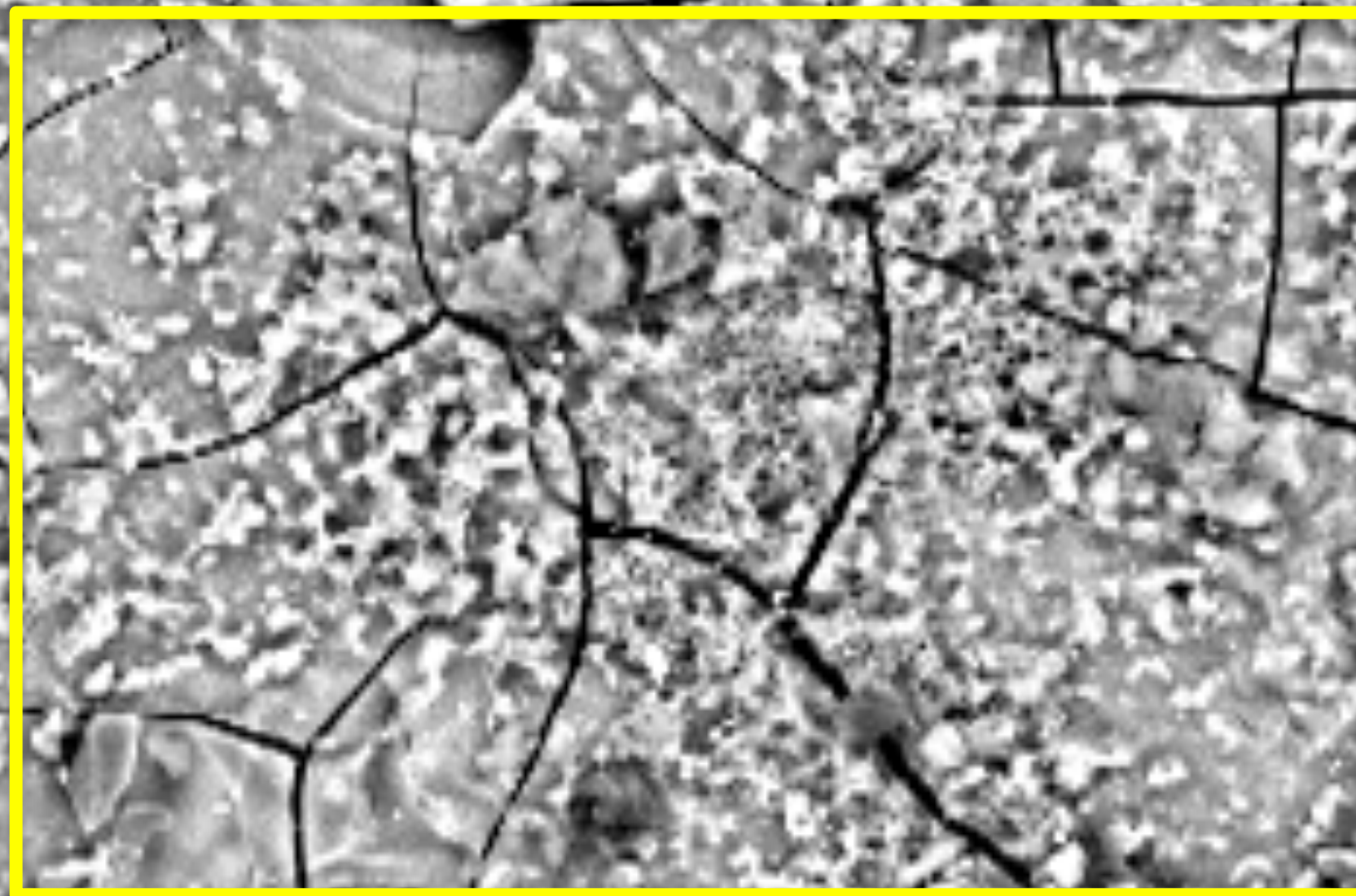




500x BSE 0.4 12.1um



Layer 2

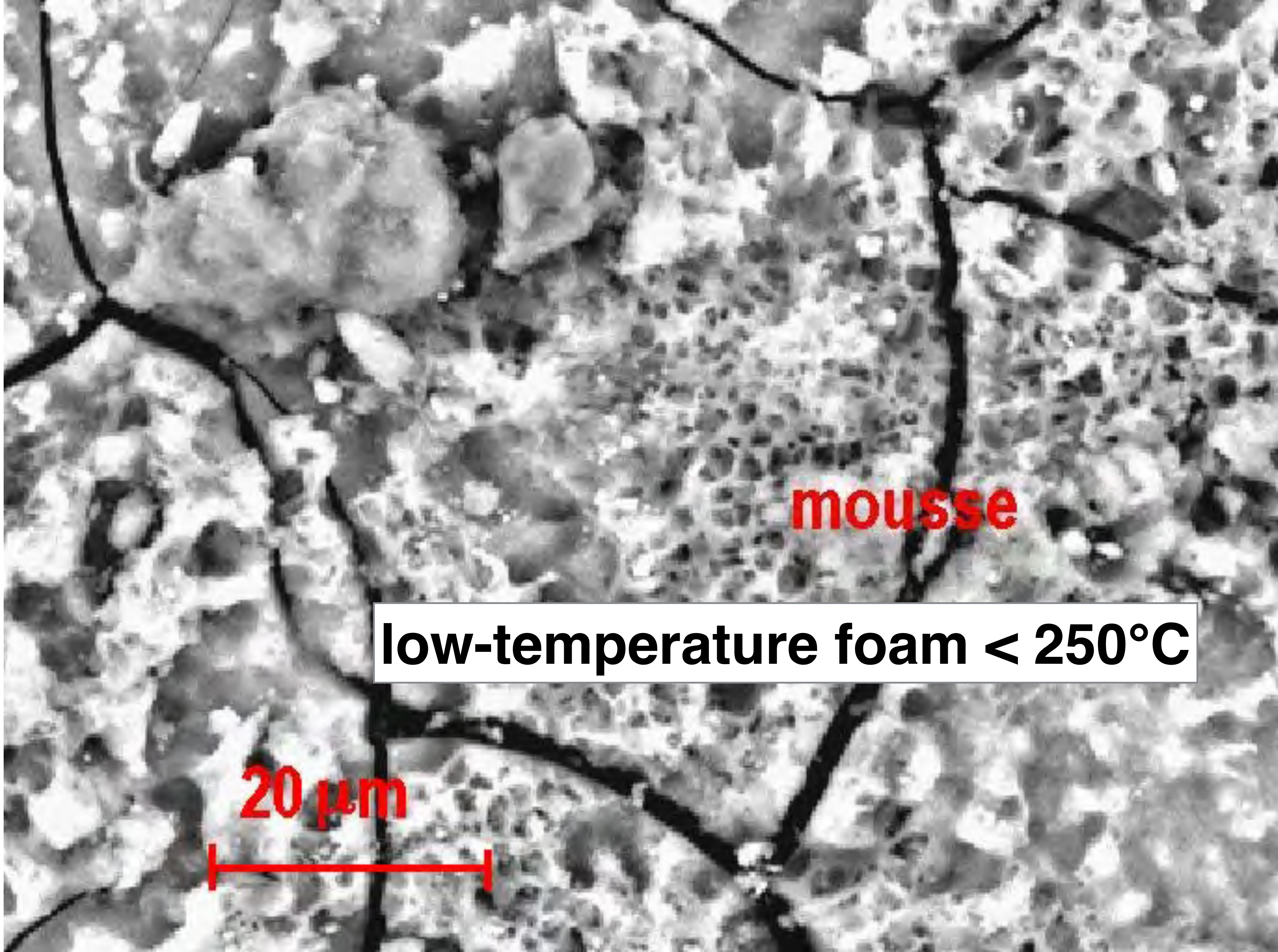


| Element      | Wt%           | At%           |
|--------------|---------------|---------------|
| Si           | 34,60         | 43,81         |
| Mg           | 7,13          | 10,43         |
| Cu           | 34,43         | 19,27         |
| Cl           | 15,20         | 15,24         |
| Ca           | 3,21          | 2,84          |
| Na           | 5,43          | 8,40          |
| <b>Total</b> | <b>100,00</b> | <b>100,00</b> |

2







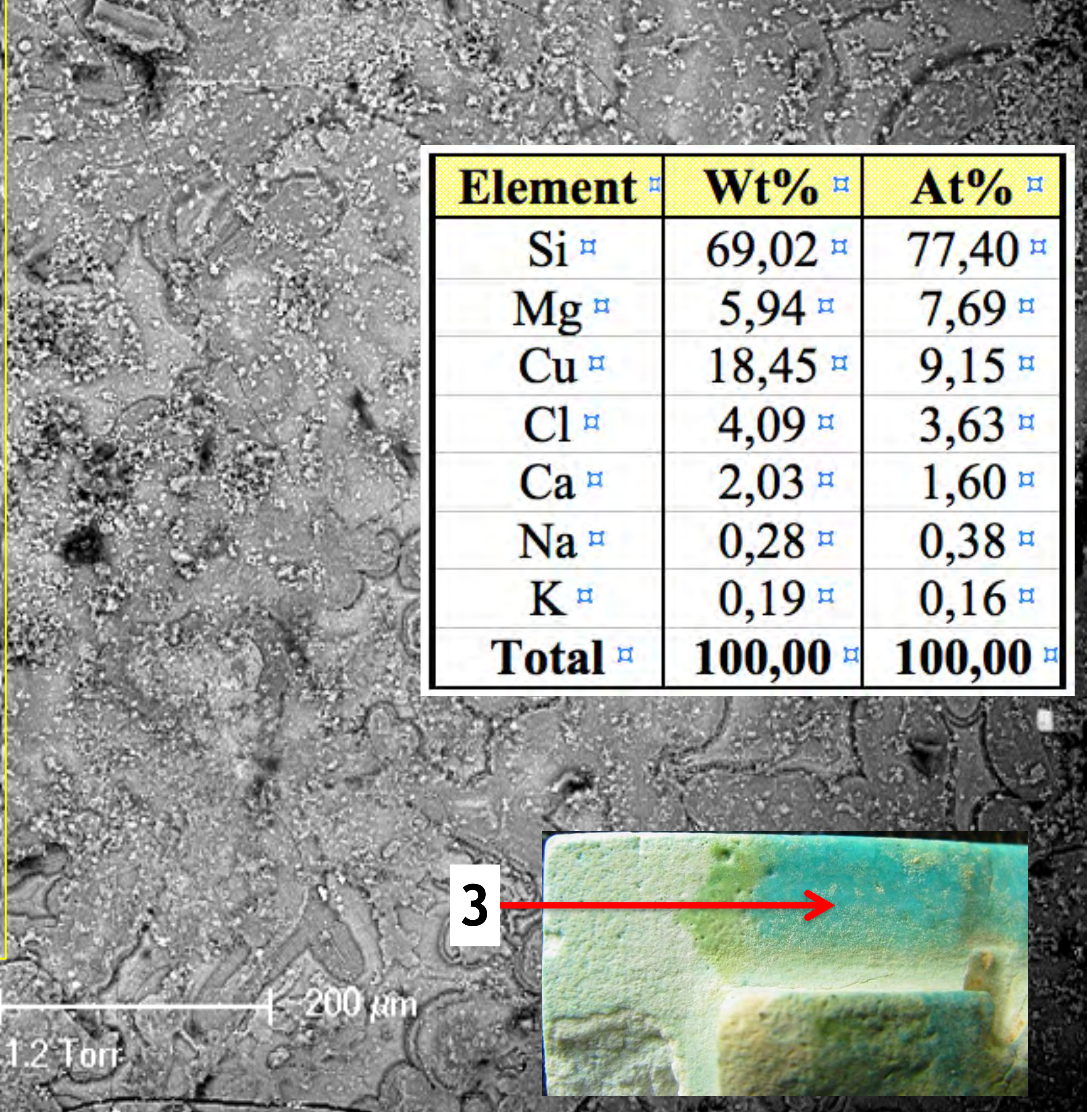
**mousse**

**low-temperature foam < 250°C**

**20 μm**







| Element      | Wt%           | At%           |
|--------------|---------------|---------------|
| Si           | 69,02         | 77,40         |
| Mg           | 5,94          | 7,69          |
| Cu           | 18,45         | 9,15          |
| Cl           | 4,09          | 3,63          |
| Ca           | 2,03          | 1,60          |
| Na           | 0,28          | 0,38          |
| K            | 0,19          | 0,16          |
| <b>Total</b> | <b>100,00</b> | <b>100,00</b> |

Magn 150x Det BSE 9.9 WD 1.2 Torr 200 μm

3





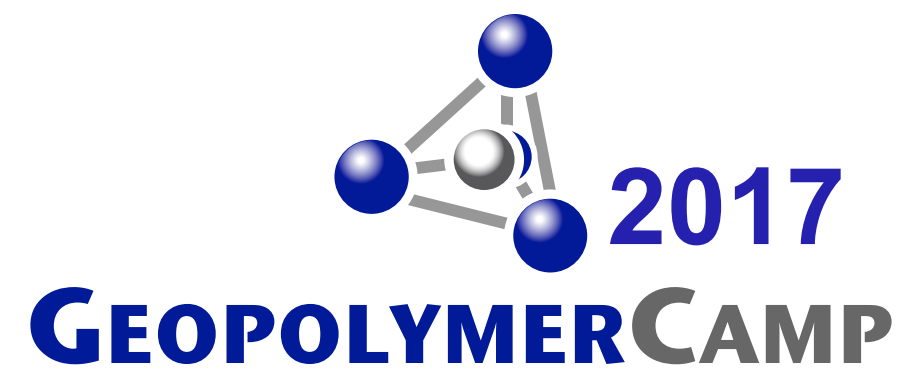
# CONCLUSIONS

Production of 30.000 tiles feasible in open garden fire at low temperature  $<250^{\circ}\text{C}$ .

The “glaze” is a coating comprising 3 successive layers:

- 1) efflorescence (**low-temperature self glazing**);
- 2) either a white calcium sulfate or/and calcium phosphate or green Na-paratacamite  $\text{Cu}_2\text{Cl}(\text{OH})_3$ ;
- 3) blue low-temperature “**geopolymer enamel**” (the only shiny external layer) with blue paratacamite  $\text{Cu}_2\text{Cl}(\text{OH})_3$ .





*Joseph Davidovits*

Geopolymer Institute

[www.geopolymer.org](http://www.geopolymer.org)

# State of the Geopolymer R&D 2017