INSTITUT GÉOPOLYMÈRE

UNIVERSITÉ de Picardie Jules Verne
CAMPUS universitaire de Saint-Quentin
PÔLE TECHNOLOGIQUE

2019 GEOPOLYMERCAMP

11th GP-Camp

LTI PÔLE TECHNOLOGIQUE SAINT-QUENTIN
UNIVERSITÉ de Picardie Jules Verne
MAG Matériaux Avancés en Géopolymère

Saint-Quentin (France)

July 8-10, 2019

State of the Geopolymer R&D 2019

Joseph Davidovits

3 Parts:

- 40th anniversary of Geopolymer Institute 1979-2019.
- Ancient Geopolymers in South-American Monuments, Pumapunku/Tiwanaku, Lake Titicaca, Bolivia.
- R&D: geopolymer science, technologies, low-CO_2 cement/concrete.

Celebrating the 40th anniversary of the Institut Géopolymère Geopolymer Institute


1972


Plastics are dangerous !!
Are organic polymers heat resistant ??

❖ No! NATURE states :

★ Only MINERALS provide fire and heat resistance

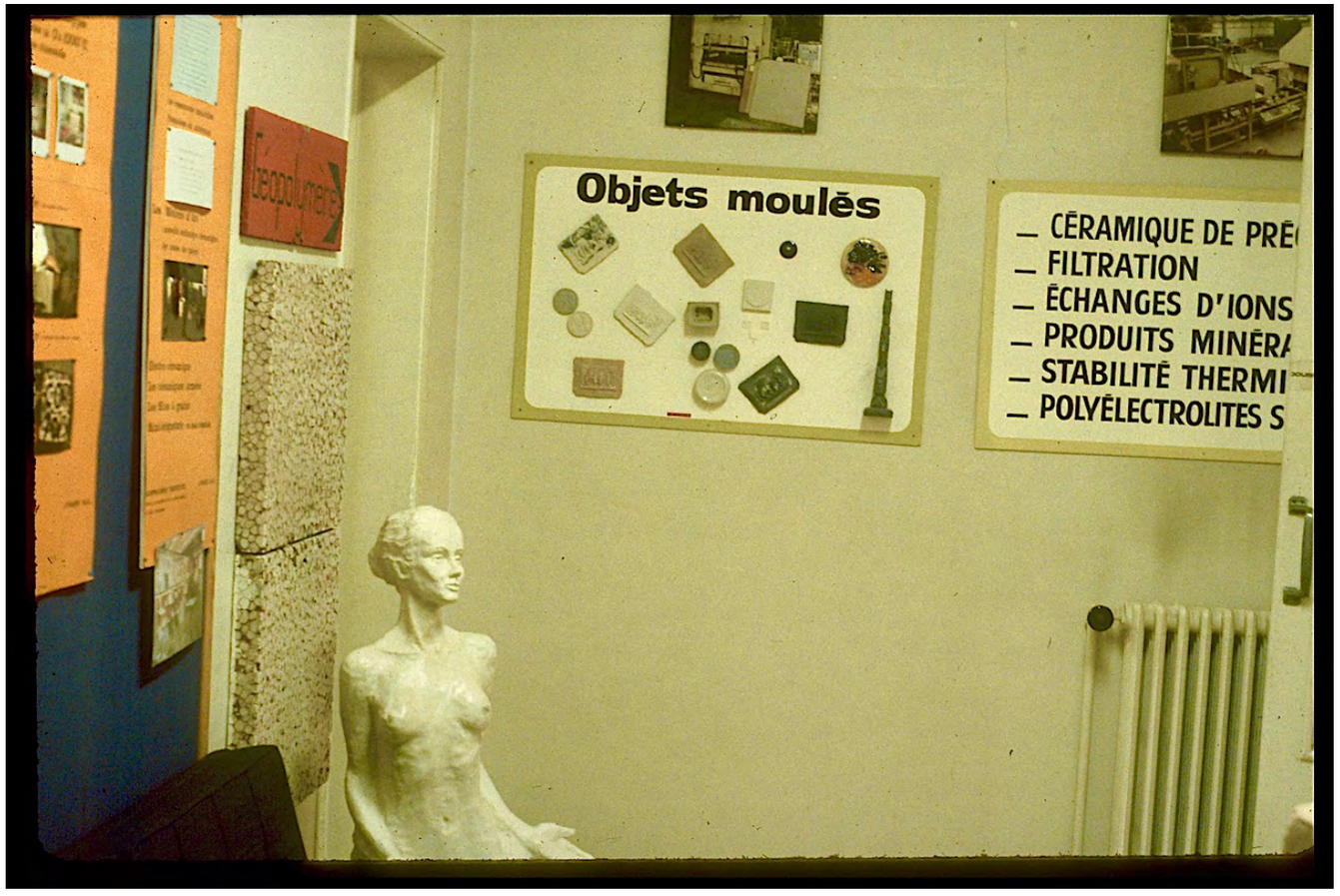
★ Target: mineral polymers.

★ Creation of CORDI S.A., private research company.

CORDI SA

20 rue de la Fère

02100 Saint-Quentin



1972 - 1983

MILESTONE in Geopolymer Chemistry and Material Sciences:

Full Paper of the communication presented at

IUPAC Symposium on Long-Term Properties of

Polymers and Polymeric Materials, Stockholm 1976, Topic III.

PROGRAMME OF THE IUPAC SYMPOSIUM ON
LONG-TERM PROPERTIES OF POLYMERS AND
POLYMERIC MATERIALS

Stockholm, August 30 - September 1,1976

1976

ORGANIZED BY

THE DEPARTMENT OF POLYMER TECHNOLOGY

THE ROYAL INSTITUTE OF TECHNOLOGY

STOCKHOLM SWEDEN

WEDNESDAY, SEPTEMBER 1 1976

TOPIC III, NEW POLYMERS OF HIGH STABILITY

14.30 - SOLIDPHASE SYNTHESIS OF A MINERAL BLOCKPOLYMER BY LOW TEMPERATURE POLYCONDENSATION OF ALUMINOSILICATE POLYMERS

by J. Davidovits (Cordi S.A., Saint-Quentin, France

Fourth Annual

Pacific Technical Conference
and Technical Displays

PLASTICS TECHNOLOGY—RECENT DEVELOPMENTS & TRENDS

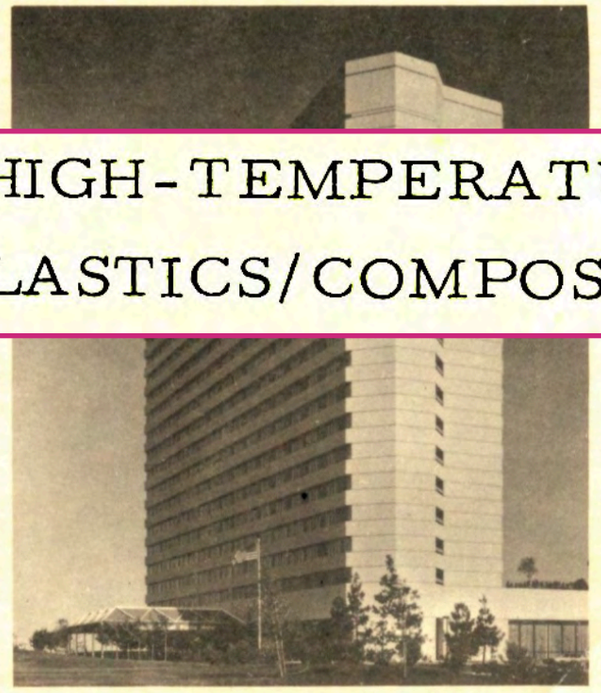
Sponsored by
Western Sections

Society of Plastics Engineers, Inc.

PACTEC '79

JANUARY 31 — FEBRUARY 2, 1979

SYNTHESIS OF NEW HIGH-TEMPERATURE GEO-POLYMERS FOR REINFORCED PLASTICS/COMPOSITES

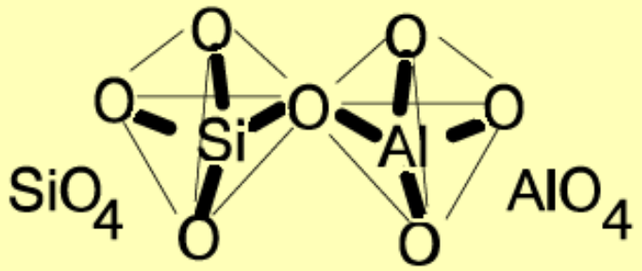


SOUTH COAST PLAZA HOTEL
COSTA MESA, CALIF.

Geopolymer Terminology

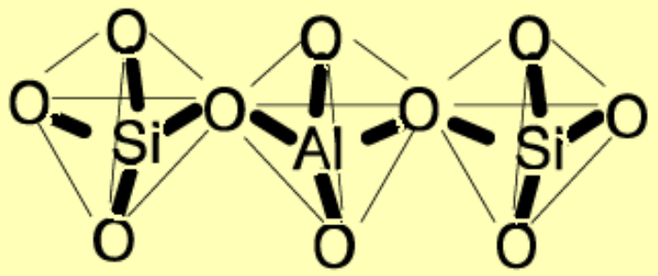
Si:Al = 1:1

Poly(sialate)
(-Si-O-Al-O-)



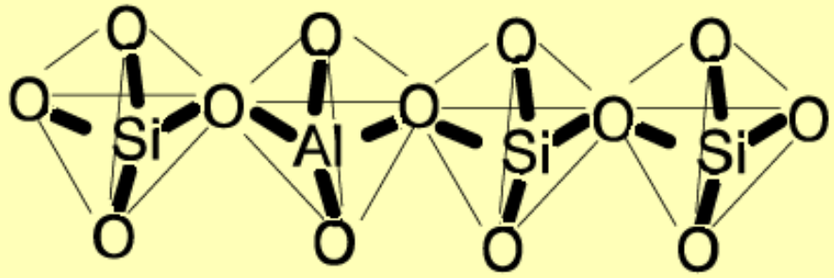
Si:Al = 2:1

Poly(sialate-siloxo)
(-Si-O-Al-O-Si-O-)



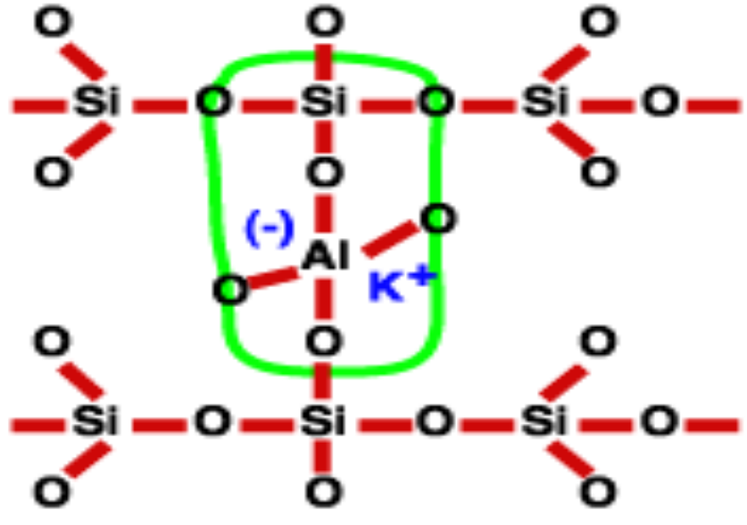
Si:Al = 3:1

Poly(sialate-disiloxo)
(-Si-O-Al-O-Si-O-Si-O-)



Si:Al > 3

Sialate link



Official Journal of the French Government

111e année. — N° 121. Samedi 26 Mai 1979.

JOURNAL OFFICIEL

DE LA RÉPUBLIQUE FRANÇAISE

ÉDITION DES LOIS ET DÉCRETS

Avis : Le *Journal officiel* complémentaire n° 121 de ce jour est encarté entre les pages 1224 et 1225 du présent numéro.

SOMMAIRE

Saturday 26 May 1979

7 mai 1979. Déclaration à la sous-préfecture de Saint-Quentin. **Institut de recherche sur les géopolymères et leurs applications.** Objet : avancement des connaissances concernant les géopolymères ; enseignement, diffusion et application de ces connaissances en sciences techniques et naturelles, en sciences humaines, en arts et lettres ainsi que la valorisation des ressources du sous-sol. Siège social : 20, rue de La Fère, 02100 Saint-Quentin.

Institut Géopolymère (Geopolymer Institute)

Research Institute on geopolymers and their applications

Mission: Advancement of knowledge concerning geopolymers; teaching, dissemination and applications of this knowledge in the technical and natural sciences, humanities, arts and literature, as well as the exploitation of the geological resources. ***Head office***: 20 rue de la Fère, Saint-Quentin.

Cement-Concrete

Global Warming

CO_2 emissions

Environmental Technologies

Archaeological Sciences

1988: *1st International Geopolymer Conference*, Université de Technologie Compiègne, France.

1999: *2nd International Geopolymer Conference*, Saint-Quentin, France.

2002: *3rd International Geopolymer Conference*, Melbourne, Australia.

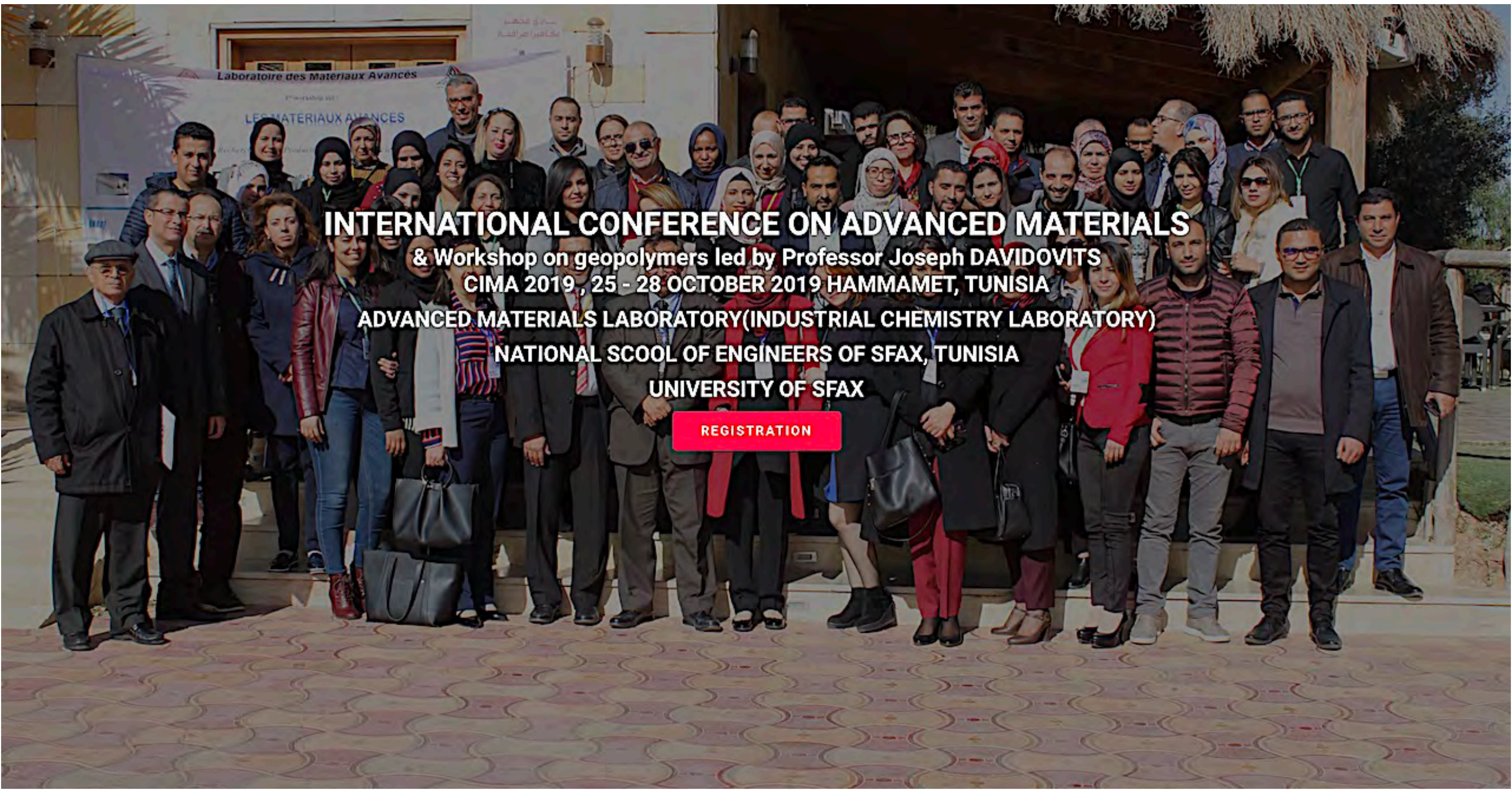
2005: *International Geopolymer World Congress*, Saint-Quentin, France, and Perth, Australia.

2009: *1st Geopolymer CAMP*, Saint-Quentin: yearly international event.

since 2009, several "National" Geopolymer gatherings or conferences

CIMA 2019: 25 - 28 OCTOBER 2019 HAMMAMET, TUNISIA

https://cima-tunisie.com



10th anniversary of GeopolymerCamp

2009 - 2019 : 10 videos of Keynotes

State of Geopolymer R & D

State of the Geopolymer R&D

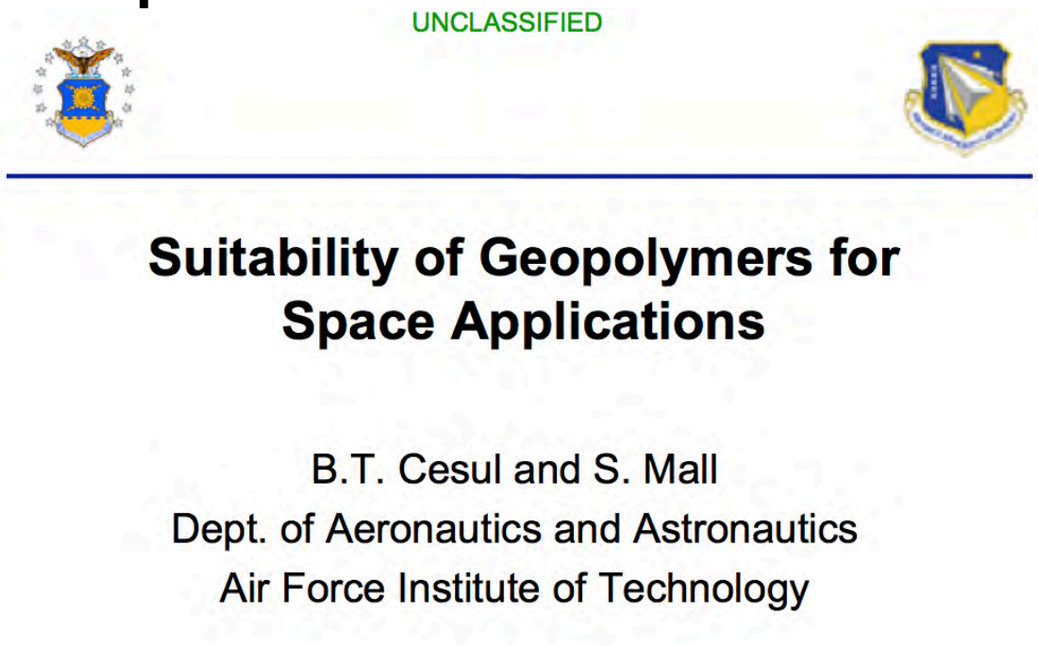
2009 : Mass Production of GP-cement. Video > 14,450 views.

2010 : Archaeology (see later).

2011 : (bad audio) Synthetic metakaolin (chemosynthetic)

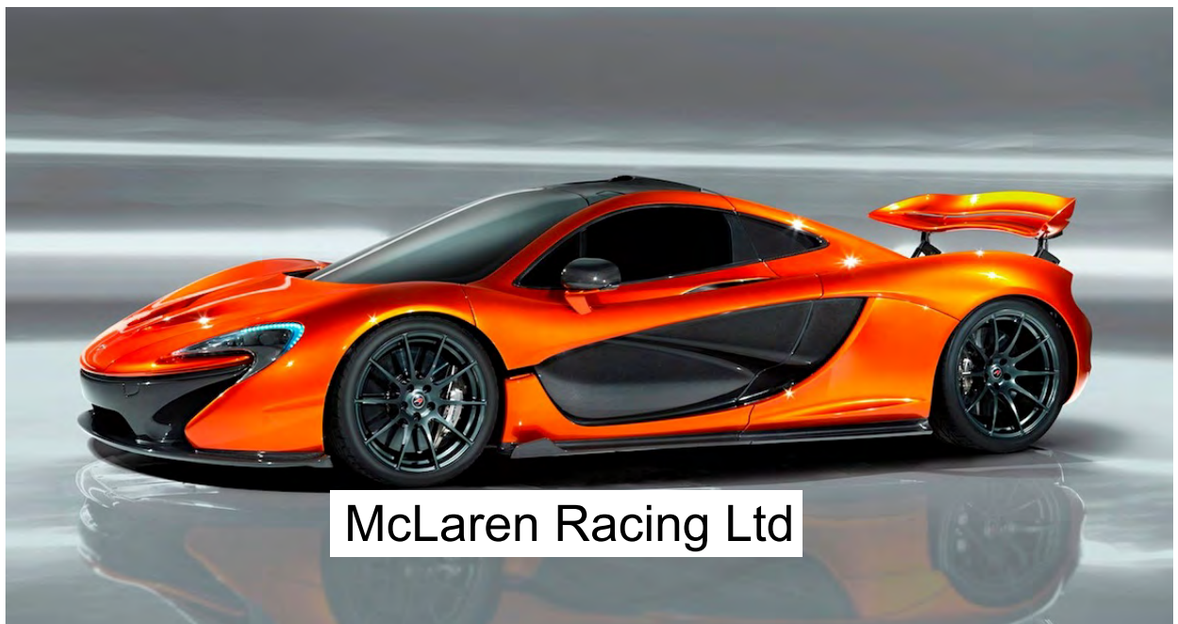
2012 : Opposition between cement chemistry terminology and geopolymer terminology (see later Why AAM are not Geopolymers).

2013 : First Webinar, Space application, geopolymer/carbon fiber composite.


UNCLASSIFIED

Suitability of Geopolymers for Space Applications

B.T. Cesul and S. Mall
Dept. of Aeronautics and Astronautics
Air Force Institute of Technology


McLaren Racing Ltd

State of the Geopolymer R&D

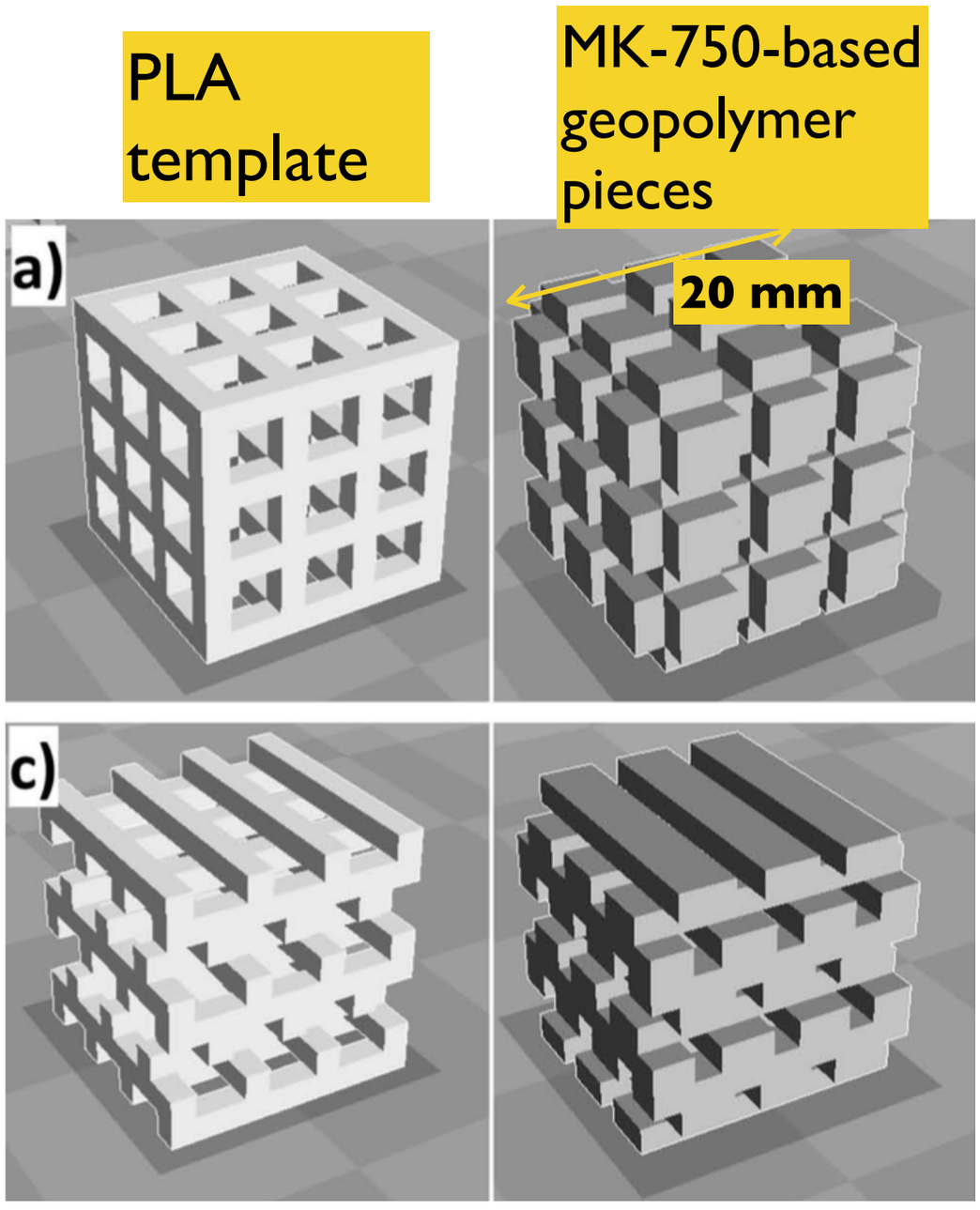
2014 : Part I of "*Why AAM are not Geopolymer*",

First public building with geopolymer concrete, Brisbane, Australia.

UNIVERSITY OF QUEENSLAND GLOBAL CHANGE INSTITUTE

State of the Geopolymer R&D

2015 : 3D-printing, Wagner's Wellcamp Airport (Toowomba, Brisbane), industrial applications (foundries, grouts, etc, several videos).



State of the Geopolymer R&D

2016 : my visits of Brisbane building and Toowomba airport (Australia).

State of the Geopolymer R&D

2017 : London's fire :

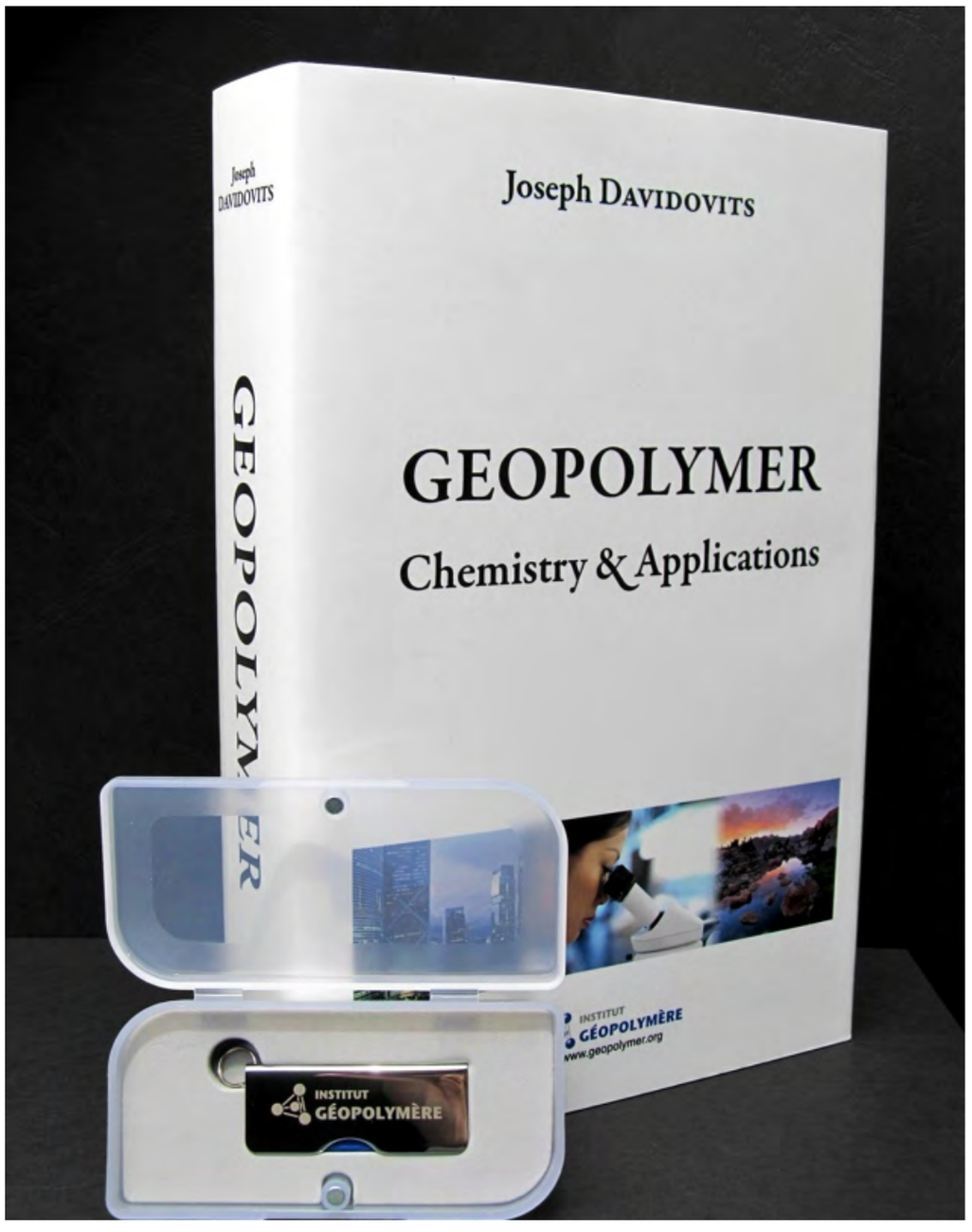
Chapter 22

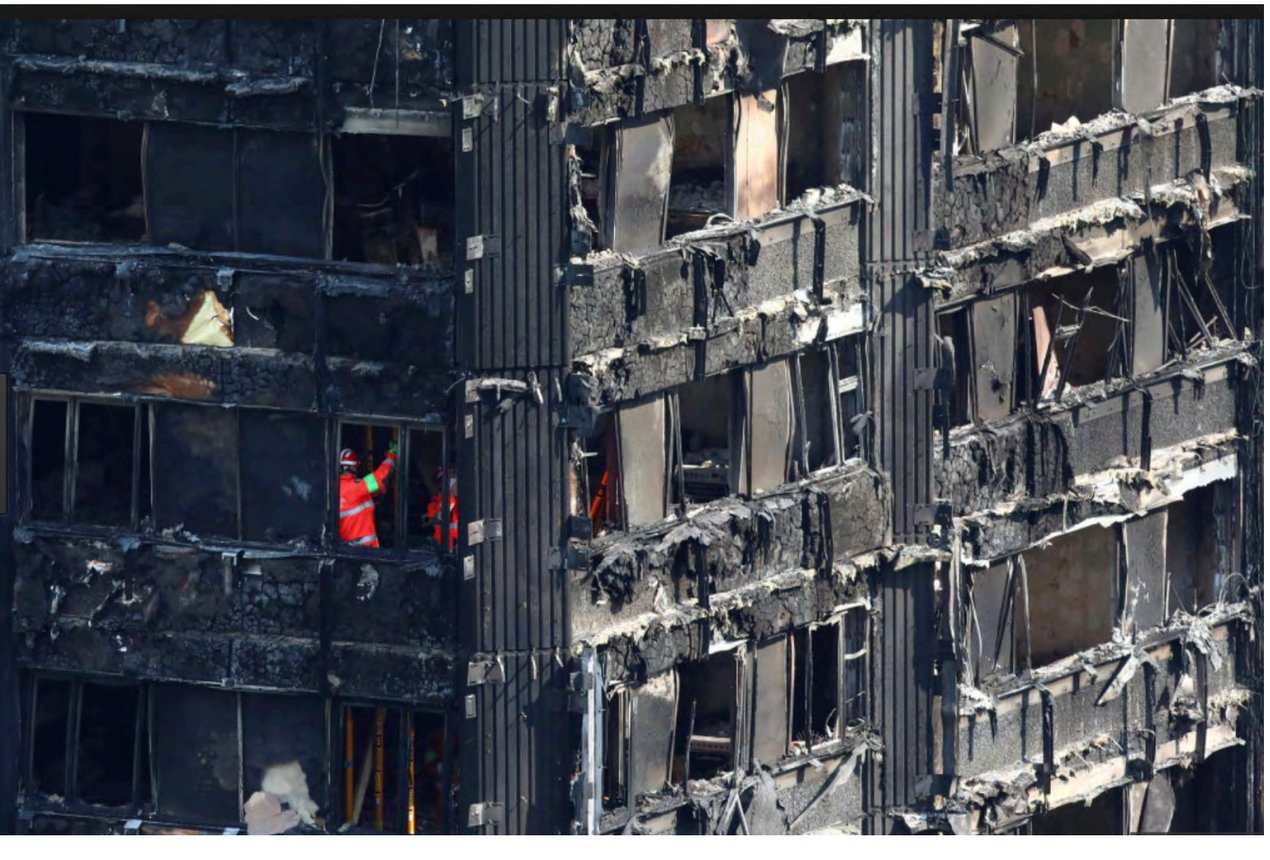
Fire and Heat resistant

Geopolymer Foam

Trolit® 1987

Too expensive !!





June 14, 2017
30 years later
London Grenfell Tower

80 people died ! Is it too expensive ?

State of the Geopolymer R&D 2010

1) Geopolymer science

2) Geopolymer technologies

3) Geopolymer Cements / Concretes

4) Geopolymer and archaeology

The Boston Globe

A new angle on pyramids

Scientists explore whether Egyptians used concrete

M.I.T.

MIT students under the direction of pr
contrarian theory. (Dina Rudick/Globe

Zahi Hawass, head of Egypt's Supreme Council of Antiquities, minced no words in assailing the concrete idea. « It's highly stupid, » he said via a spokesman. « The pyramids are made from solid blocks of quarried limestone. To suggest otherwise is idiotic and insulting ».

Oldest geopolymer artifact

25 000 years old !

The Venus from Dolni Vestonice (CZ)


a)


b)


c)


d)


e)


f)

State of the Geopolymer R&D

State of the Geopolymer R&D

1) Geopolymer science

2) Geopolymer technologies

3) Geopolymer Cements / Concretes

4) Geopolymer and archaeology

State of the Geopolymer R&D 2019

1) Geopolymer and archaeology

2) Geopolymer technologies

3) Geopolymer science

4) Geopolymer Cements / Concretes

State of the Geopolymer R&D 2019

1) Geopolymer and archaeology

2) Geopolymer technologies

3) Geopolymer science

4) Geopolymer Cements / Concretes

2018
GEOPOLYMERCAMP

Ancient Geopolymer in South-American Monuments, 600 AD

Joint research program between *Geopolymer Institute* and *Universidad Catolica San Pablo*, Arequipa, Peru.

2017-2018

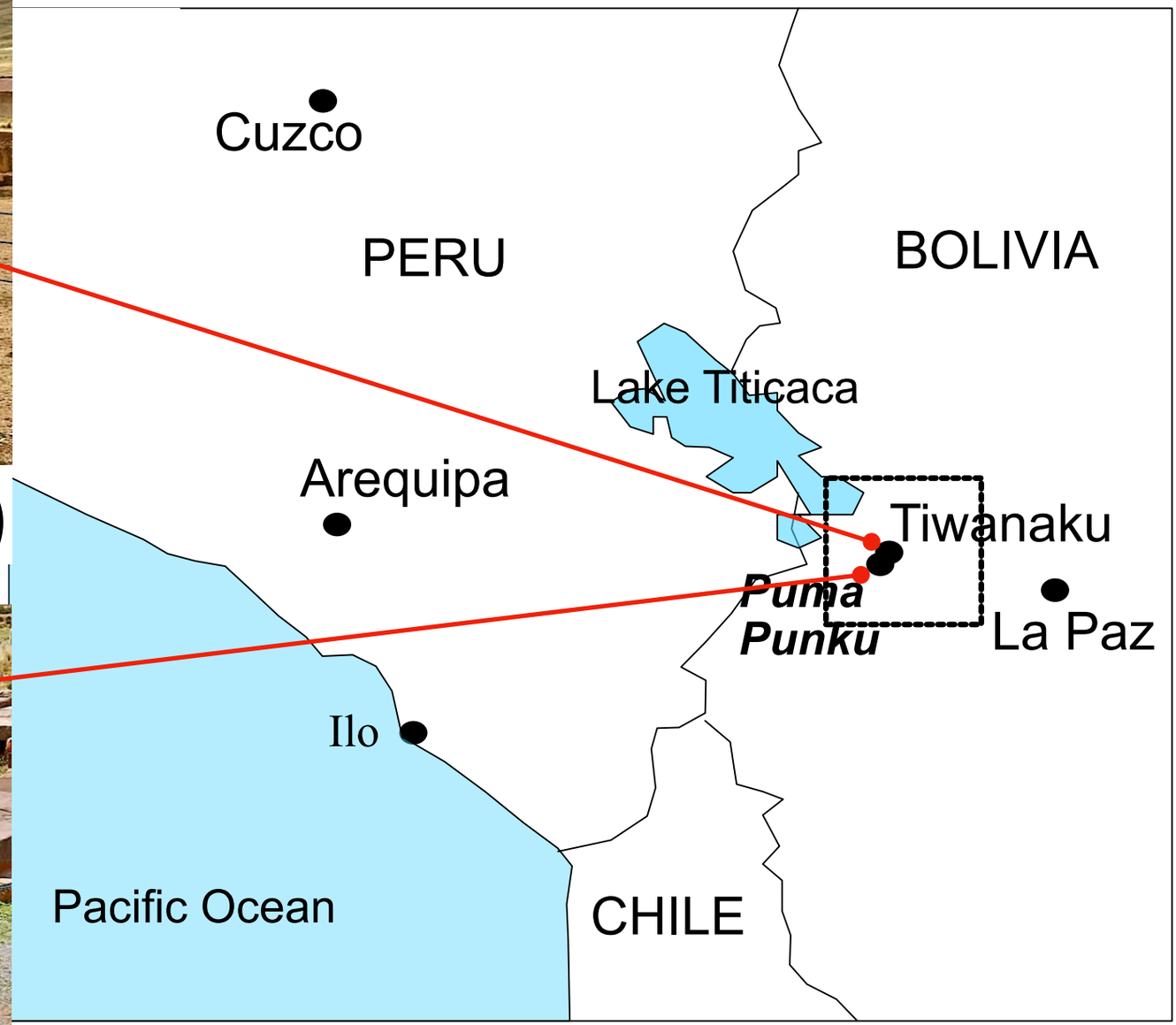
First results for Tiwanaku / Pumapunku, Bolivia.

Universidad Católica San Pablo

INSTITUT GÉOPOLYMÈRE

Andesite (volcanic)

Red sandstone

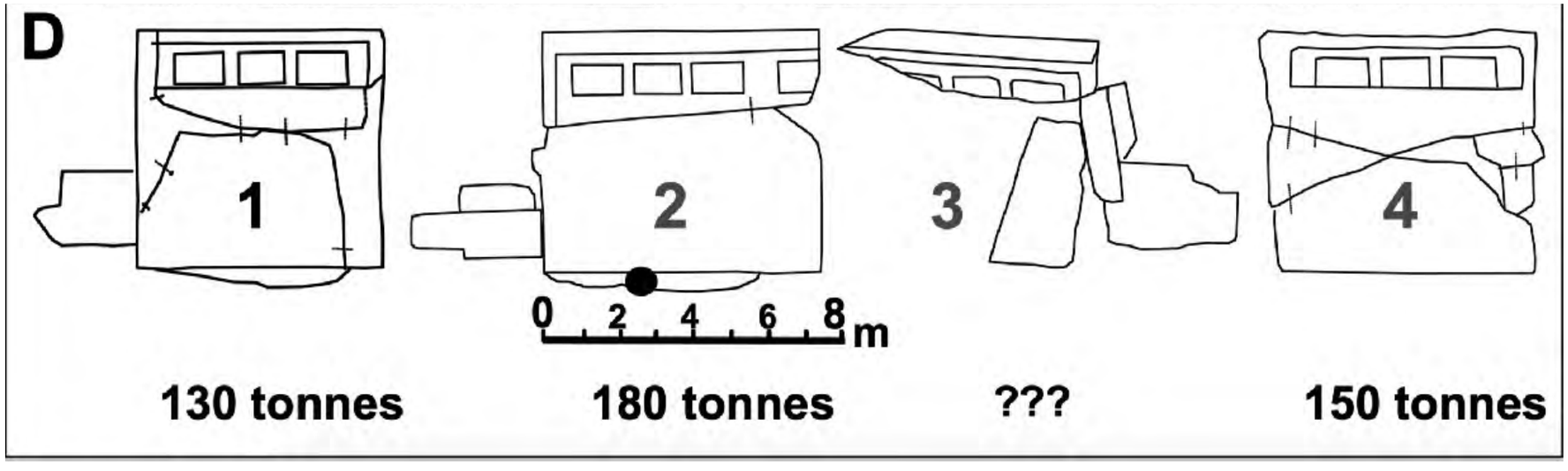


Two different methods:

1) For red sandstone megaliths:
   Geopolymer in alkaline-medium.
2) For grey andesite structures:
   Geopolymer in acidic-medium.

Method nr. I

Pumapunku red sandstone megaliths



Contents lists available at ScienceDirect

Materials Letters

2019

journal homepage: www.elsevier.com/locate/mlblue

Materials Letters 235 (2019) 120–124

https://doi.org/10.1016/j.matlet.2018.10.033

Ancient geopolymer in south-American monument. SEM and petrographic evidence

Joseph Davidovits [a,*], Luis Huaman [b], Ralph Davidovits [c]

[a] Geopolymer Institute, 02100 Saint-Quentin, France
[b] Escuela Profesional de Geología, U.N.S.A., and CITEM, U.C.S.P., Arequipa, Peru
[c] MAG (Matériaux avancés en géopolymères), LTI-EA 3899, Université de Picardie Jules Verne, 02100 Saint-Quentin, France

ARTICLE INFO

Article history:
Received 25 April 2018
Received in revised form 20 August 2018
Accepted 6 October 2018
Available online 8 October 2018

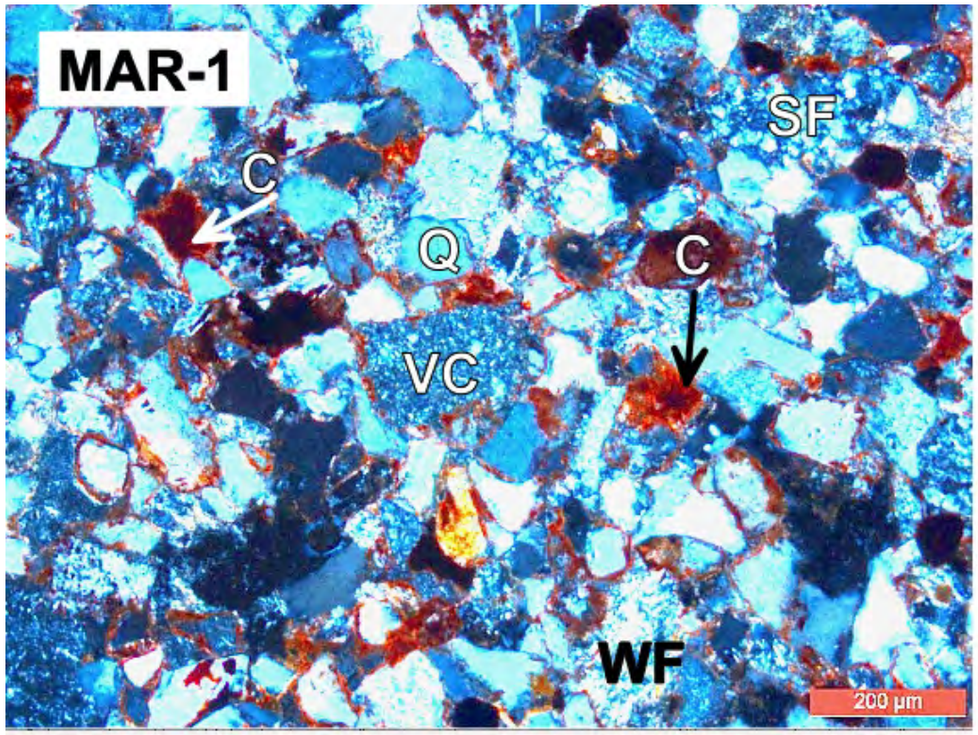
online 8 october 2018

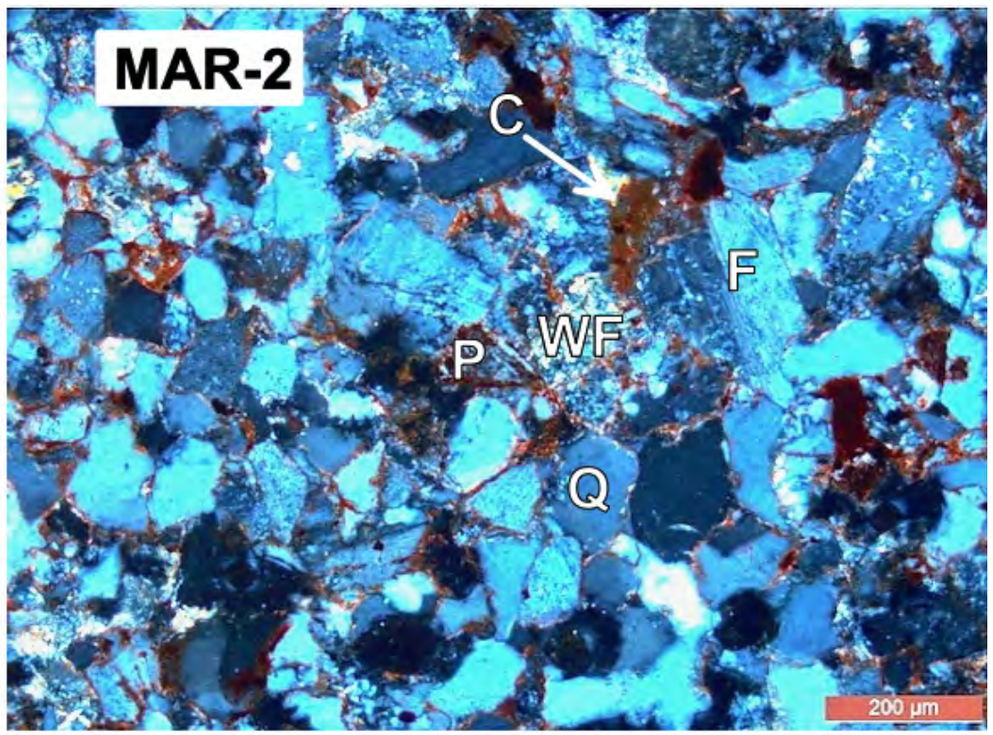
Grain boundaries
Microstructure

ABSTRACT

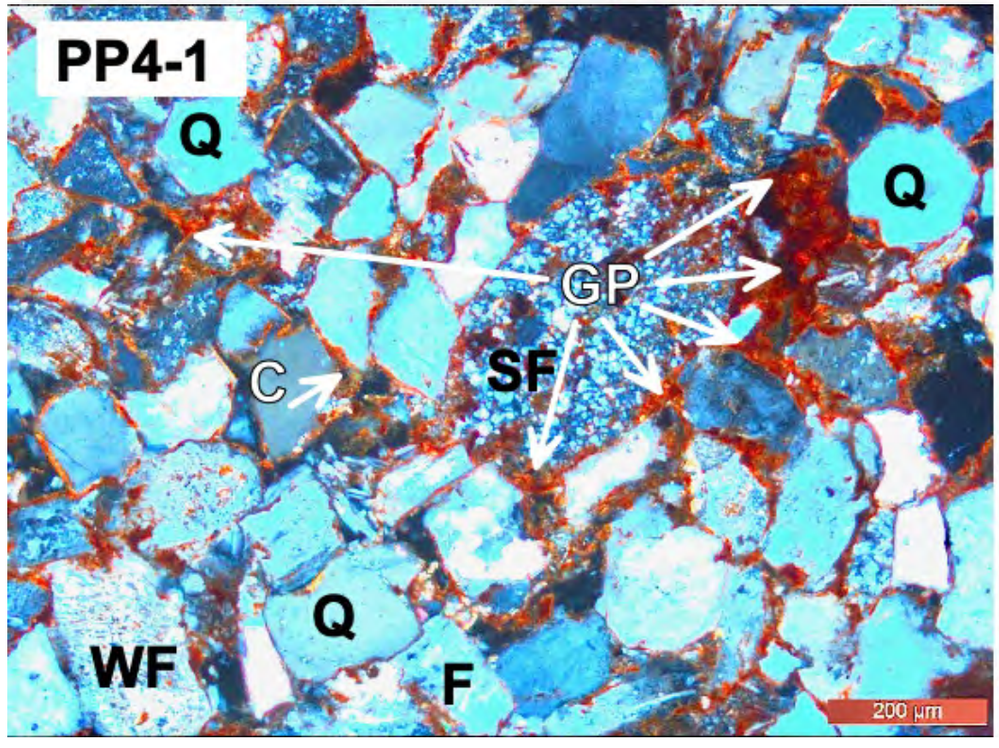
The make-up of the sandstone megalithic blocks, weighing between 130 and 180 tonnes each, from Pumapunku -Tiwanaku, Bolivia, was compared with three geological sandstone sites from the area. The SEM/EDS, XRD and thin section results suggest that the sandstone megalithic blocks consist of sandstone grains from the Kallamarka geological site, cemented with an amorphous ferro-sialate geopolymer matrix formed by human intervention, by the addition of extra alkaline salt (natron) from the Laguna Cachi in the Altiplano, Bolivia.

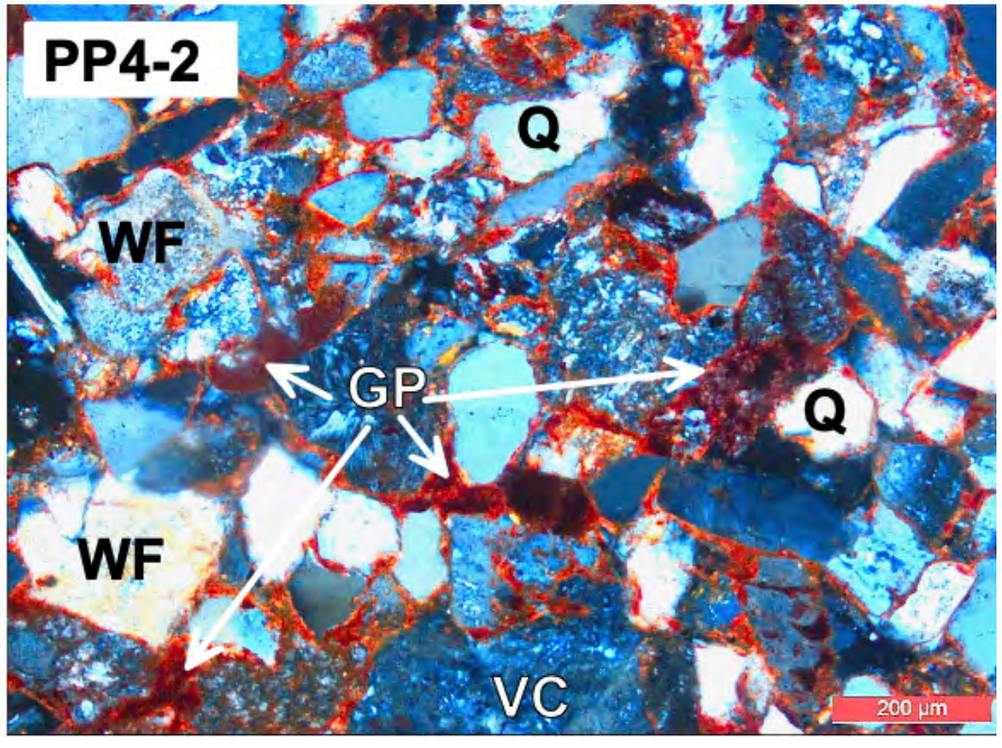
Geological site Marka



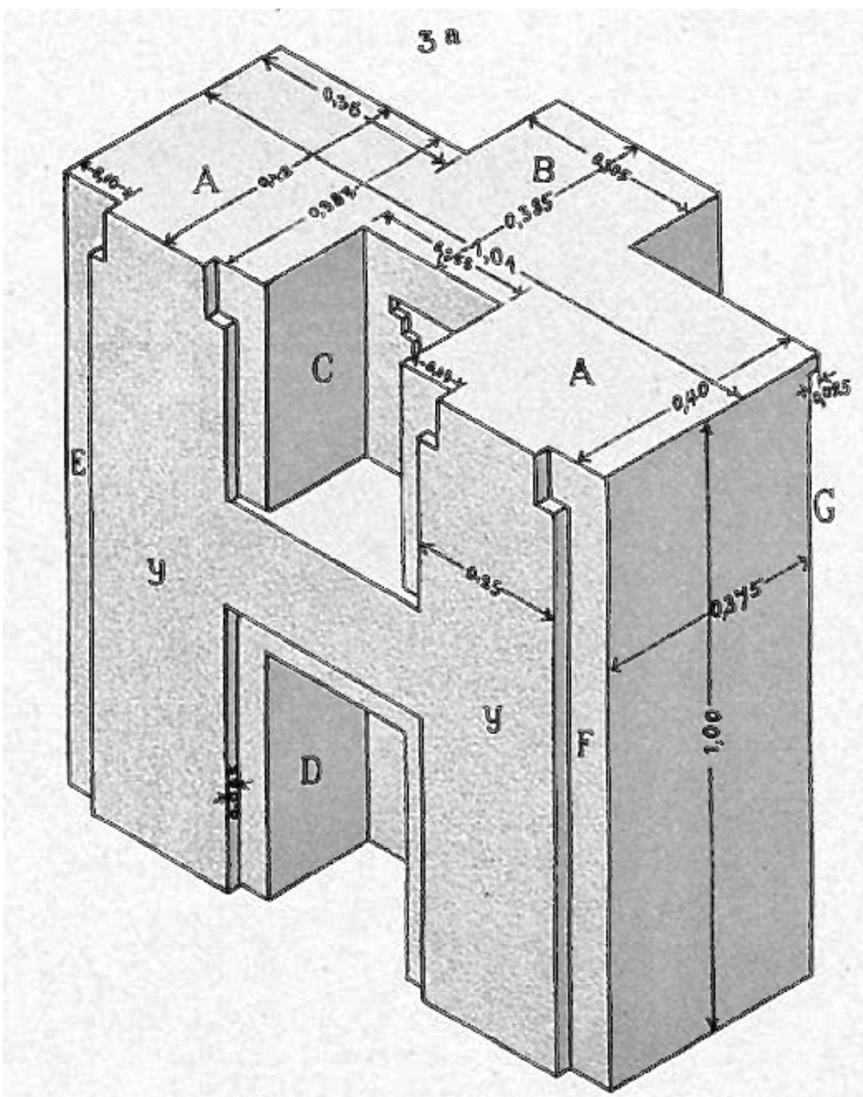


Pumapunku monument





Method nr. 2



Stüble-Uhle (1892)

H structures, 1 meter high andesite stone,
Mohs hardness ca. 6-7 (7=quartz),
density d=2.58 kg/l.

Contents lists available at ScienceDirect

Ceramics International

Ceramics International, 45 (2019) 7385-7389

journal homepage: www.elsevier.com/locate/ceramint

2019

CERAMICS INTERNATIONAL

Please cite this article as: Davidovits, J., Ceramics International, https://doi.org/10.1016/j.ceramint.2019.01.024

Ancient organo-mineral geopolymer in South-American Monuments: Organic matter in andesite stone. SEM and petrographic evidence

Joseph Davidovits[a,*], Luis Huaman[b], Ralph Davidovits[c]

[a] Geopolymer Institute, 02100 Saint-Quentin, France

[b] Escuela Profesional de Geología, U.N.S.A., and CITEM, U.C.S.P., Arequipa, Peru

[c] MAG (Matériaux avancés en géopolymères), LTI, Université de Picardie Jules Verne, 02100 Saint-Quentin, France

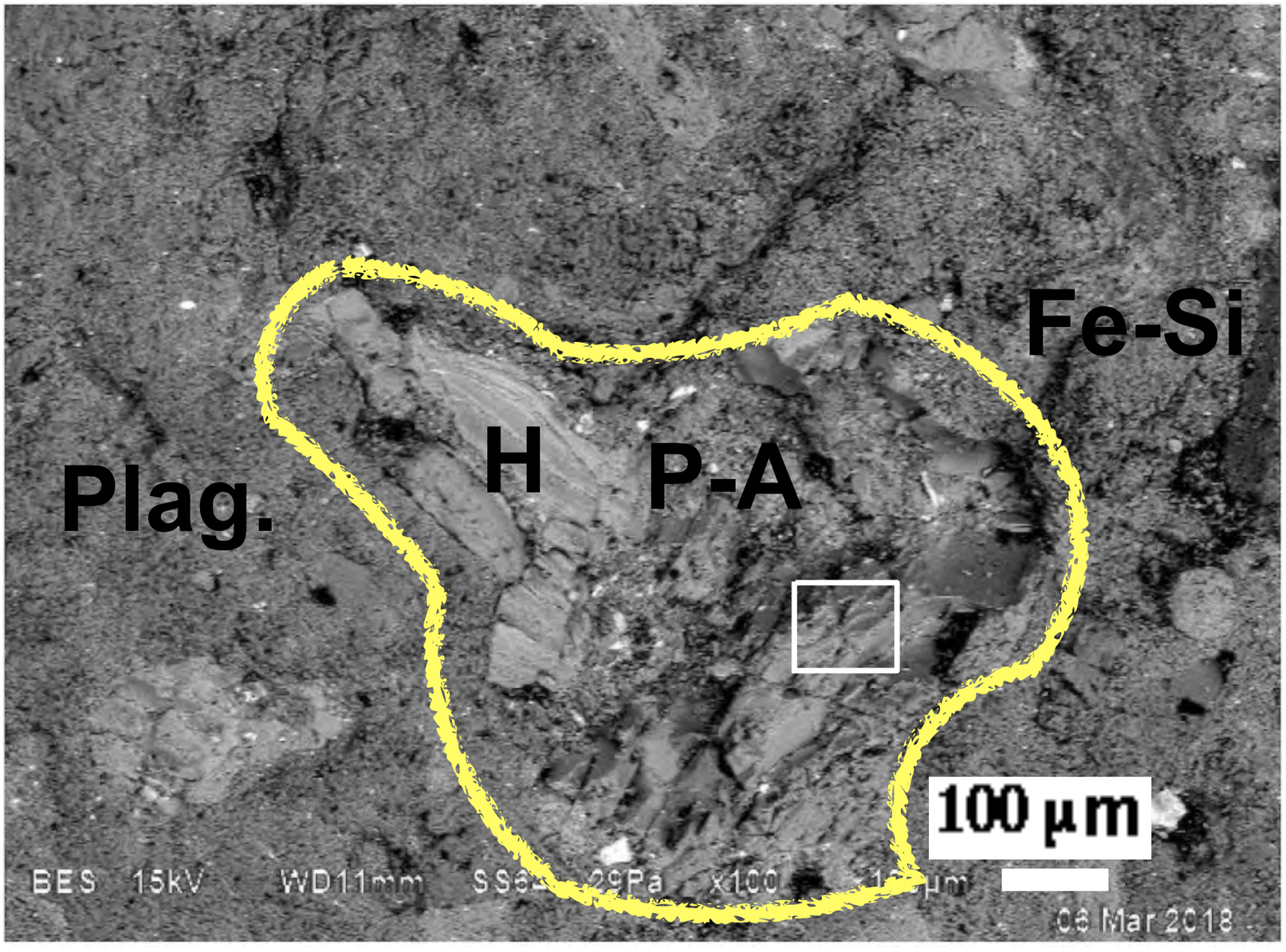
ARTICLE INFO

Keywords:
Geopolymer
Carbon
Precursors: organic
Structural applications

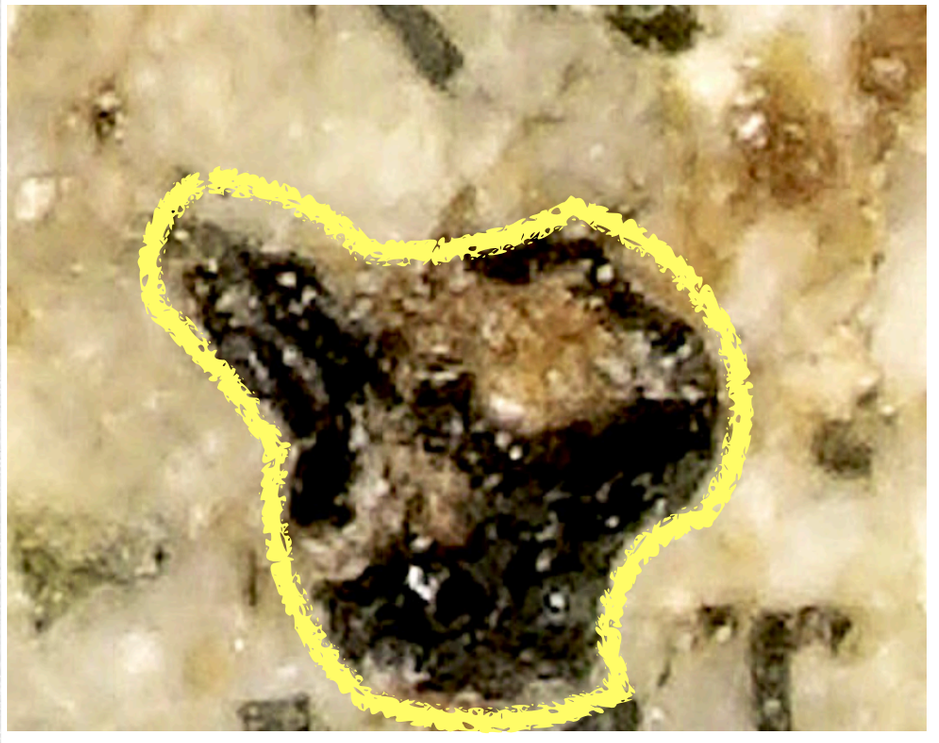
online 04 January 2019

ABSTRACT

A recent study has shown the presence of artificial construction materials in pre-Columbian monuments at Pumapunku-Tiwanaku, Bolivia. In addition to ancient geopolymer sandstone-concrete megalithic slabs, the Pumapunku site contains puzzling "H" structures made of andesitic volcanic stone. The SEM study of this gray andesite shows the presence of organic matter: carbon, nitrogen, and minerals: Na, Mg, Al, Si, P, S, Cl, K, Ca. Organic matter is very unusual, if not impossible in a solid volcanic stone and suggests ceramic-like man-made stone. Our research demonstrates that these architectural components manufactured 1400 years ago (ca. CE 600) were fashioned with a type of organo-mineral precursor.

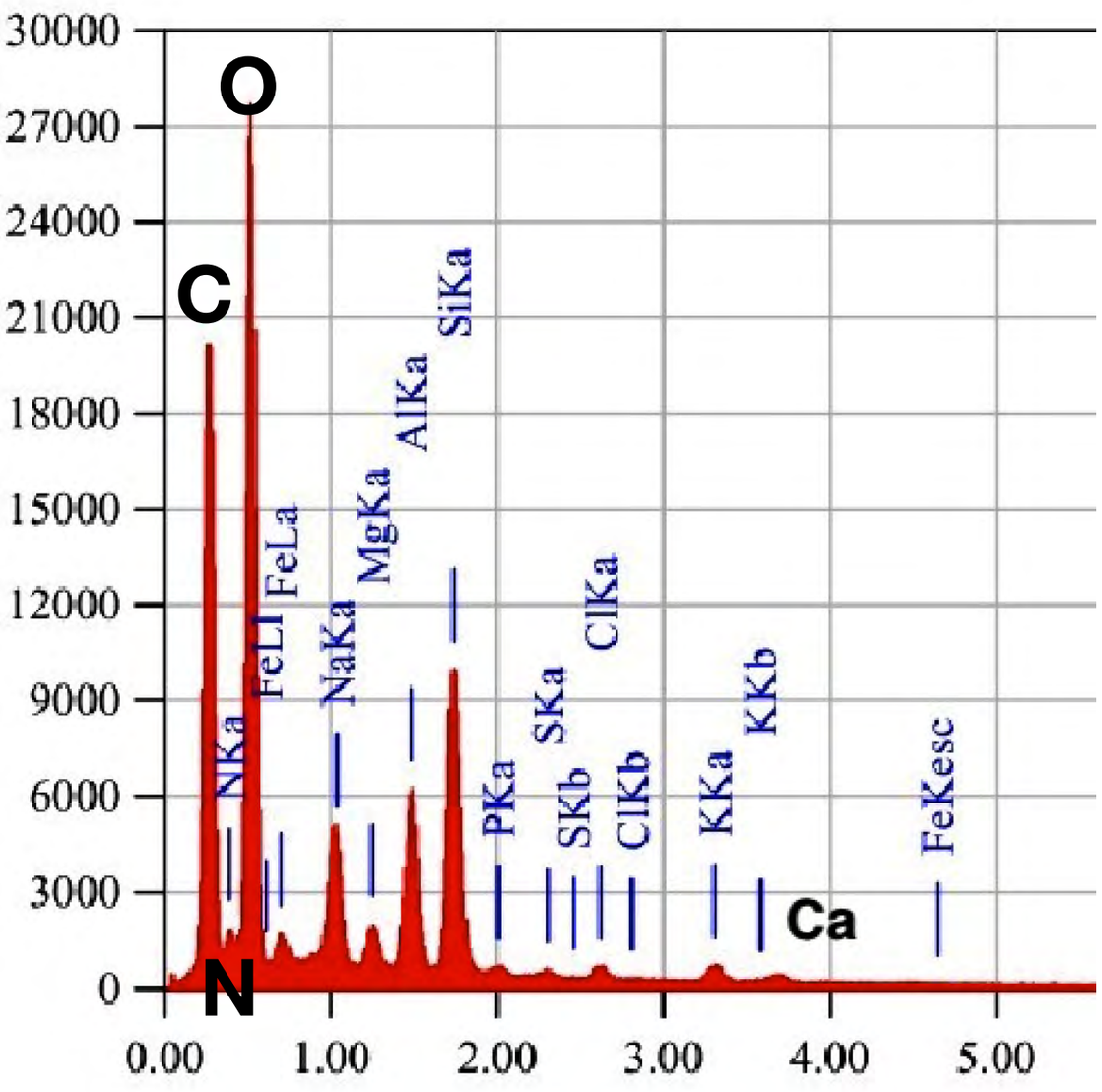


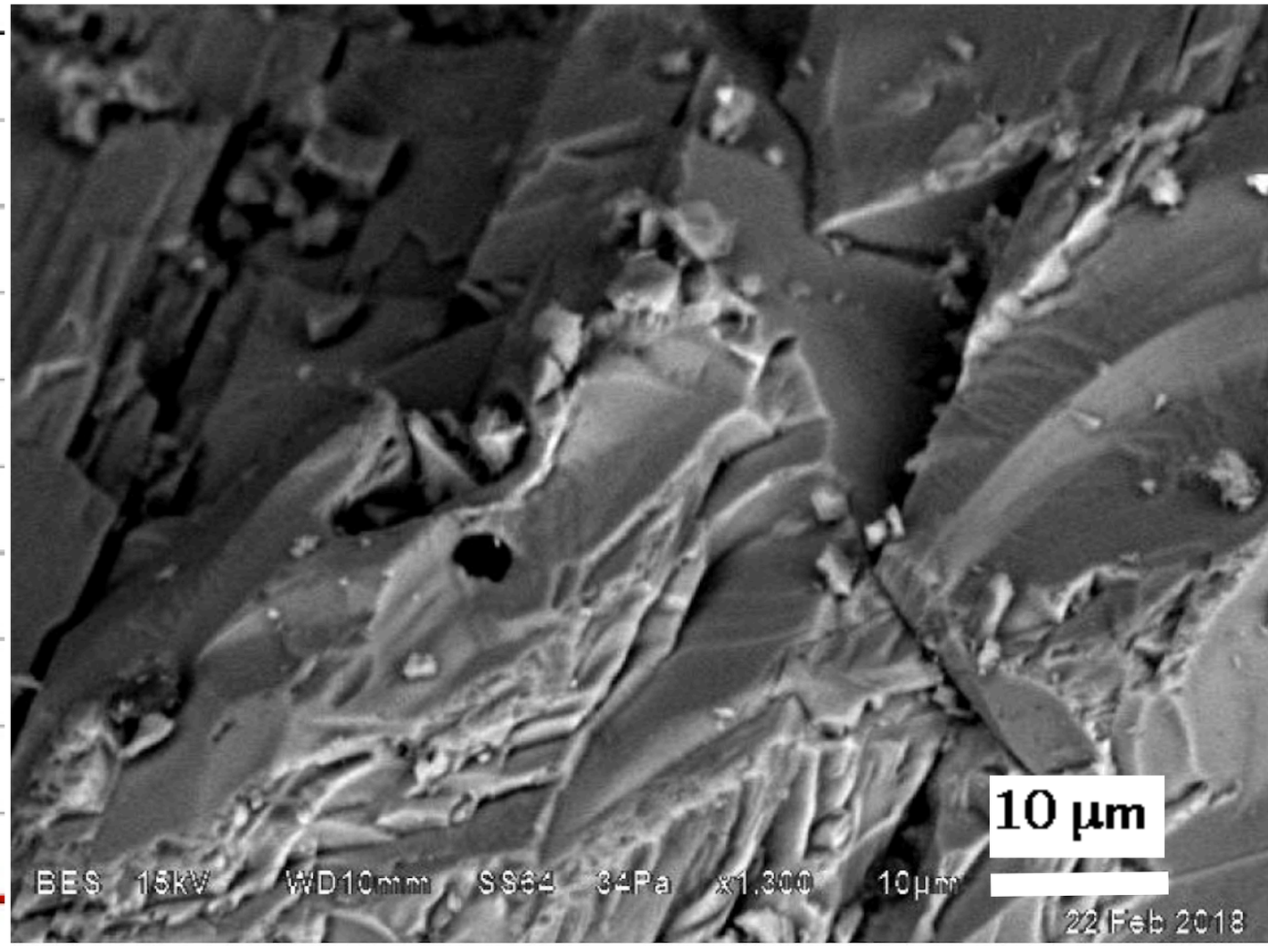
Point 4



Organic matter (binder ?) in a volcanic rock

Point 4





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www.geopolymer.org

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Features articles

Tiahuanaco Monuments (Tiwanaku / Pumapunku), Bolivia are made of geopolymer artificial stones created 1400 years ago.

3 Mar 2019

Transcript of the conference by Prof. Joseph Davidovits, held at the Geopolymer Camp 2018, in the Session: Ancient Technologies, Tuesday, July 10, 2018,...

Latest articles

11th Geopolymer Camp and Tutorial

6 Mar 2019

#26 Standardized Method in Testing Commercial Metakaolins for Geopolymer Formulations.

5 Mar 2019

Tiahuanaco Monuments (Tiwanaku / Pumapunku), Bolivia are made of geopolymer artificial stones created 1400 years ago.

3 Mar 2019

Révélations à Tiwanaku / Puma Punku : Présence de géopolymères

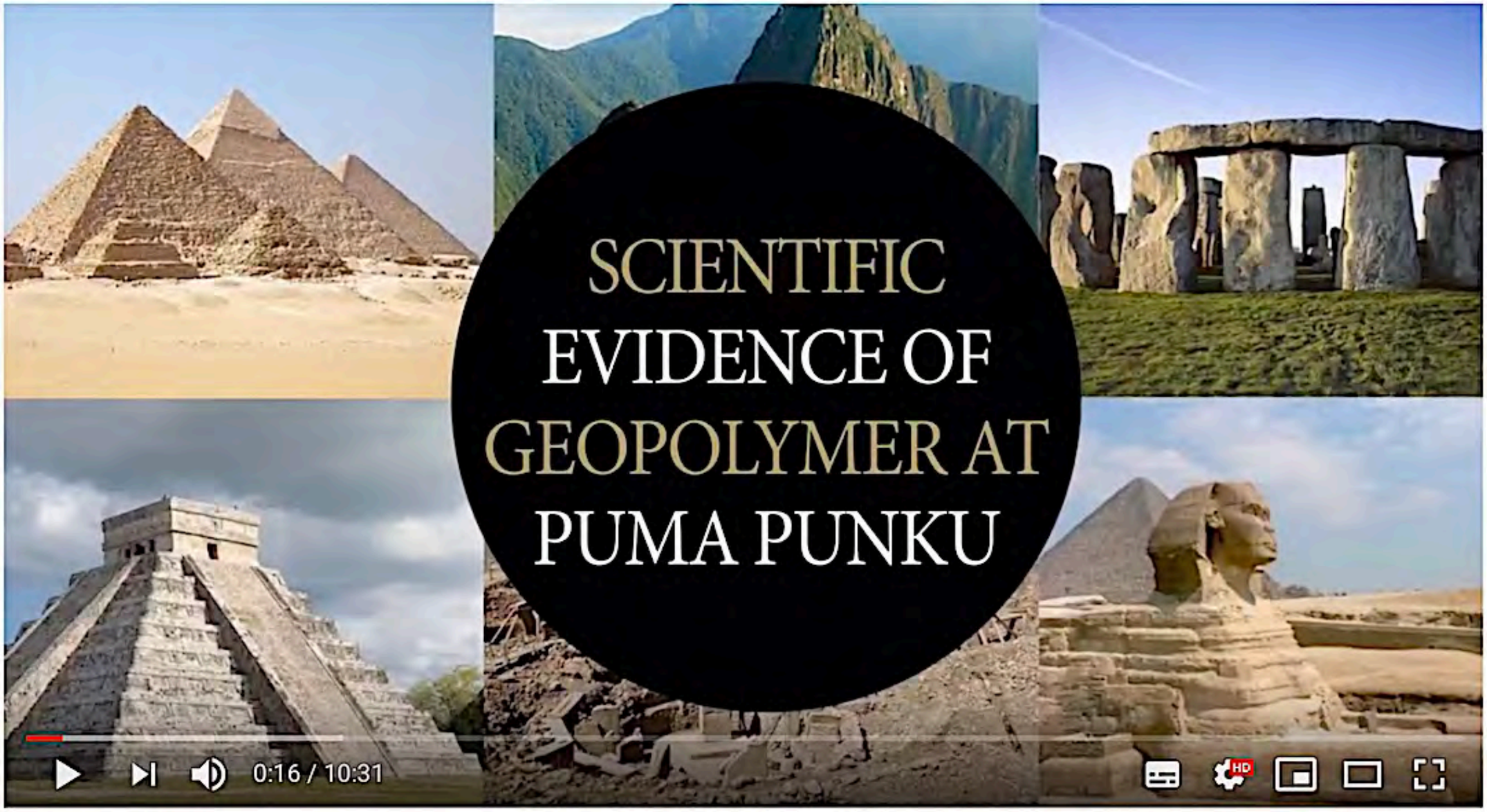
>130,500 views

1,7 K 264 PARTAGER ENREGISTRER ...

Deï Mian
Ajoutée le 27 juil. 2018

Capture d'écran

S'ABONNER



Scientific Evidence that the Puma Punku H-Blocks Are Artificial Geopolymer | Ancient Architects

> 268,300 views

Ancient Architects
Ajoutée le 8 mars 2019

Contents lists available at ScienceDirect
Ceramics International
journal homepage: www.elsevier.com/locate/ceramint

Ancient organo-mineral geopolymer in South-American Monuments: Organic matter in andesite stone. SEM and petrographic evidence

Joseph Davidovits[a,*], Luis Huaman[b], Ralph Davidovits[c]

[a] Geopolymer Institute, 02100 Saint-Quentin, France
[b] Escuela Profesional de Geología, U.N.S.A., and CITEM, U.C.S.P., Arequipa, Peru
[c] MAC (Matériaux avancés en géopolymère) LTD, Université de Picardie Jules Verne, 02100 Saint-Quentin, France

ARTICLE INFO

Keywords:
Geopolymer
Carbon
Precursors organic
Structural applications

ABSTRACT

A recent study has shown the presence of artificial construction materials in pre-Columbian monuments at Pumapunku-Tiwanaku, Bolivia. In addition to ancient geopolymer sandstone-concrete megalithic slabs, the Pumapunku site contains puzzling "H" structures made of andesitic volcanic stone. The SEM study of this gray andesite shows the presence of organic matter: carbon, nitrogen, and minerals: Na, Mg, Al, Si, P, S, Cl, K, Ca. Organic matter is very unusual, if not impossible in a solid volcanic stone and suggests ceramic-like man-made stone. Our research demonstrates that these architectural components manufactured 1400 years ago (ca. CE 600) were fashioned with a type of organo-mineral precursor.

1. Introduction

A recent study carried out on monuments in the South American Andes, on the Altiplano (Fig. 1A), at Pumapunku-Tiwanaku, Bolivia, Davidovits et al. [1], dealt with the less known site of Pumapunku. It was built 1400 years ago (ca. CE 600) by the Tiwanaku Empire, one of the civilizations of the pre-Columbian Americas, 800 years before the rise of the Inca empire. The 150–180 tonnes sandstone blocks are a 1400-year-old geopolymer sandstone concrete, Fig. 1C.

But, the most controversial aspect of the Pumapunku site is its puzzling smaller items, 1 m high, coined "H" sculptures, made of andesitic volcanic stone (Fig. 1D-E). They have unprecedented smooth finishes, perfectly flat faces at exact 90° interior and exterior right angles. Historian architects are wondering how such perfect stonework could have been achieved with simple stone tools [2].

The SEM study of this gray andesite shows the presence of organic matter: carbon, nitrogen, and mineral elements. Organic matter is very unusual in a solid volcanic stone and points to man-made stone. Some petrographic studies were carried out by Ponce Sanguines et al. [3] on the sandstone quarries and megalithic slabs. Yet, they did not perform any petrographic study on the andesitic volcanic sculptures. 19th-century travelers had agreed that the andesite stone originated mainly from the volcano Cerro Khapia in the southern part of the Lake Titicaca [4]. More recently Janusek et al. [5] confirmed that the volcano was the principal source of andesitic material at Pumapunku/Tiwanaku.

2. Materials and methods

2.1. Andesite samples

Numerous andesite fragments are scattered on the site (Fig. 2A). They are outside the protected monument area. By carefully choosing this debris consisting of pieces of monumental stones with the characteristically very flat surface, we were able to get our samples PP1 (Fig. 2 A-B).

2.2. Analytical methods

The thin 30 μm thick sections were studied under transmitted light (polarized or not) with a Leica 4500 DMP optical microscope. The results for andesite are shown in Fig. 2D. The scanning electron microscope SEM images and EDS analysis for the elements were acquired using a JEOL JSM-6510LV scanning electron microscope. The results are shown in Fig. 3

3. Results

3.1. Optical microscope

Under reflecting light, the flat surface of PP1A sample shows white feldspar plagioclase crystals and dark elongated minerals which are

* Corresponding author.
E-mail address: joseph@geopolymer.org (J. Davidovits).

http://dx.doi.org/10.1016/j.ceramint.2015.01.084
Available online 04 January 2015

4:05 / 10:31

Scientific Evidence that the Puma Punku H-Blocks Are Artificial Geopolymer | Ancient Architects

> 268,300 views

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Ceramics International

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28 June 2019

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Ancient organo-mineral geopolymer in South-American Monuments: Organic matter in andesite stone. SEM and petrographic evidence

15 April 2019

Joseph Davidovits | Luis Huaman | Ralph Davidovits

State of the Geopolymer R&D 2019

1) Geopolymer and archaeology

2) Geopolymer technologies

3) Geopolymer science

4) Geopolymer Cements / Concretes

Geopolymer binder / resin

paint / coating / grout

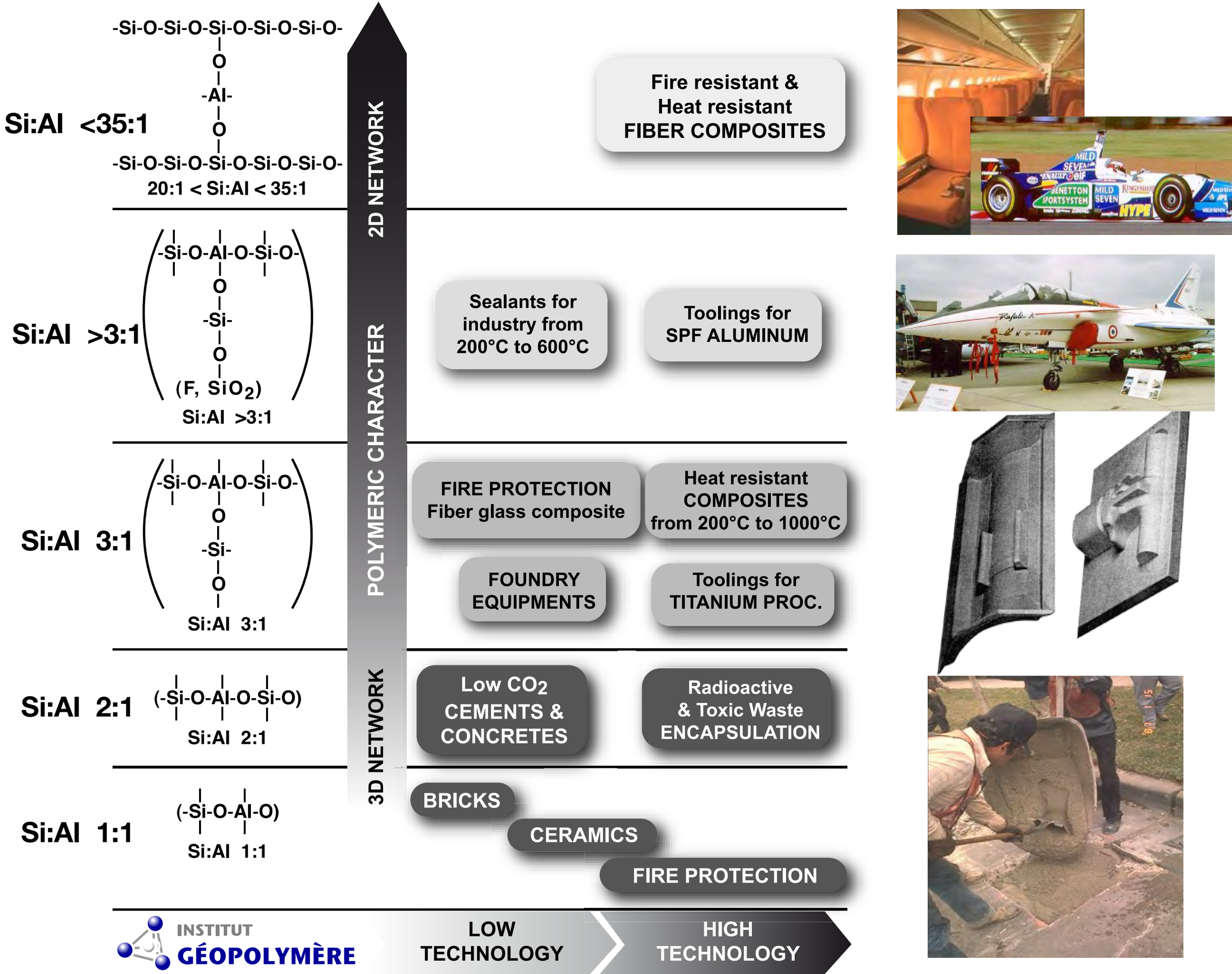
Geopolymer foam

Geopolymer cement

Geopolymer concrete

Geopolymer carbon/composite

Geopolymer ceramics


-Si-O-Si-O-Si-O-Si-O-Si-O-
O
-Al-
O
-Si-O-Si-O-Si-O-Si-O-Si-O-
Si:Al <35:1
20:1 < Si:Al < 35:1
2D NETWORK
POLYMERIC CHARACTER
3D NETWORK
Fire resistant & Heat resistant FIBER COMPOSITES
-Si-O-Al-O-Si-O-
O
-Si-
O
(F, SiO2)
Si:Al >3:1
Sealants for industry from 200°C to 600°C
Toolings for SPF ALUMINUM
Si:Al 3:1
FIRE PROTECTION Fiber glass composite
Heat resistant COMPOSITES from 200°C to 1000°C
FOUNDRY EQUIPMENTS
Toolings for TITANIUM PROC.
Si:Al 2:1
(-Si-O-Al-O-Si-O)
Low CO2 CEMENTS & CONCRETES
Radioactive & Toxic Waste ENCAPSULATION
Si:Al 1:1
(-Si-O-Al-O)
BRICKS
CERAMICS
FIRE PROTECTION
INSTITUT GÉOPOLYMÈRE
LOW TECHNOLOGY
HIGH TECHNOLOGY

BASF Germany

PCI-GEOFUG® ,
geopolymer grout and
binder

www.pci-augsburg.de

Milliken Infrastructures USA

Geopolymer mortar systems and grouts for use in rehabilitation

infrastructure.milliken.com

ASK Chemicals (Ashland) Germany

INOTEC Inorganic Binder System, geopolymer binder for foundries

www.ask-chemicals.com

BMW SUPPLIER **INNOVATION** AWARD 2014

Wagners Australia

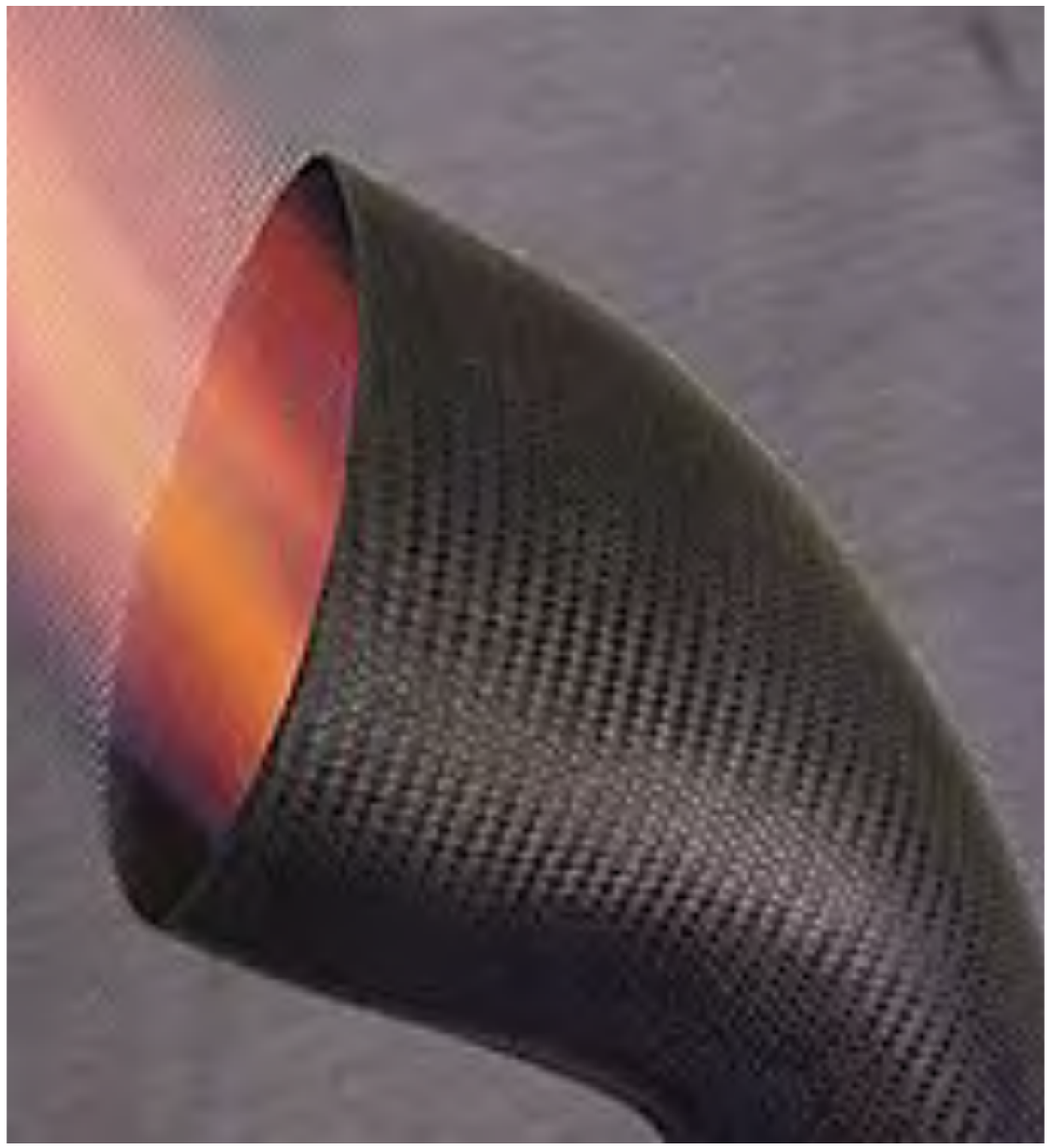
Earth Friendly Concrete: fly ash / slag geopolymer concrete for infrastructures

www.wagner.com.au

Pyromeral Systems France

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

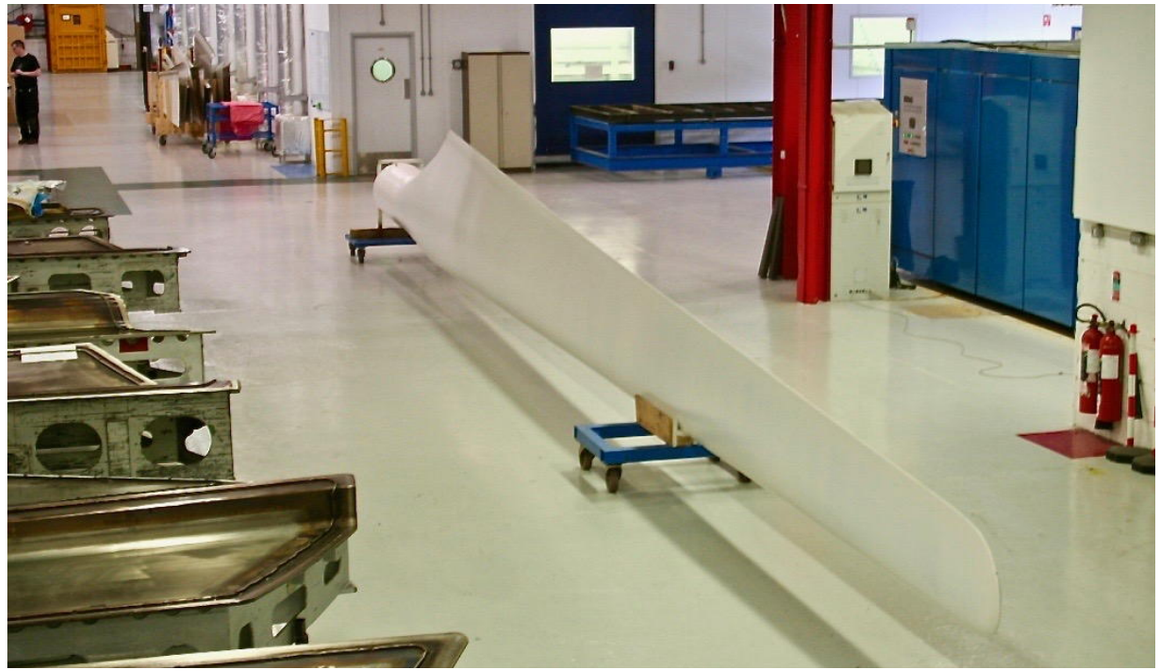
www.pyromeral.com



Éire Composites Ireland

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

www.eirecomposites.com

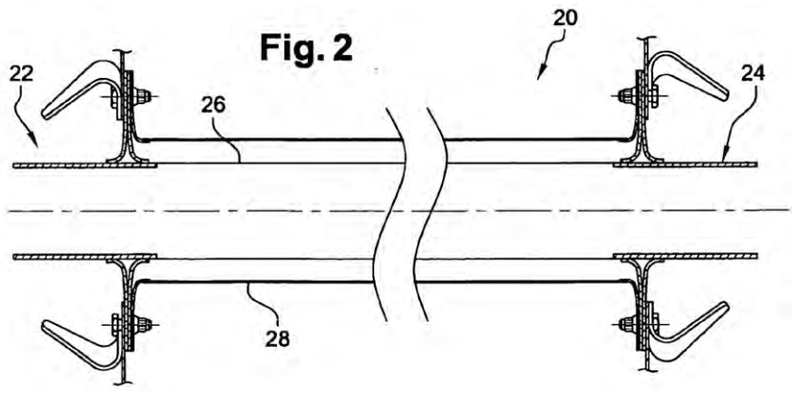


Airbus France

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

Skoberne
Germany

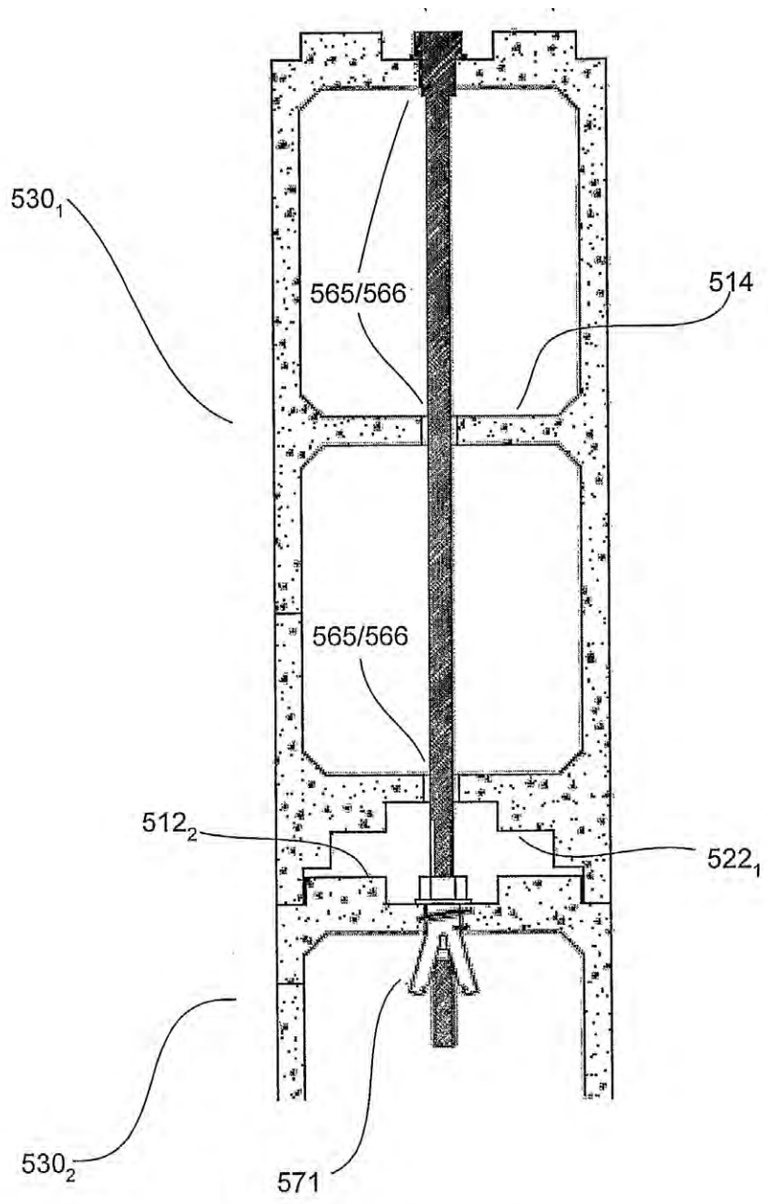
Skobifix 30
Fireproof condensing
chimney for hot gas
exhaust made of
geopolymer foam.

www.skoberne.de

Matakii Panels Singapore

Patent WO/ 2009/025620
Precast geopolymer panels

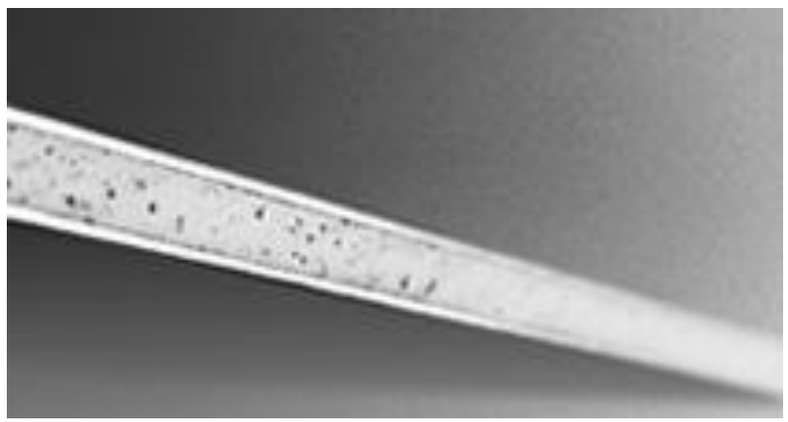
www.matakiipanels.com



NU-Core
A2FR
China

Geopolymer Fireproof Composite Panels

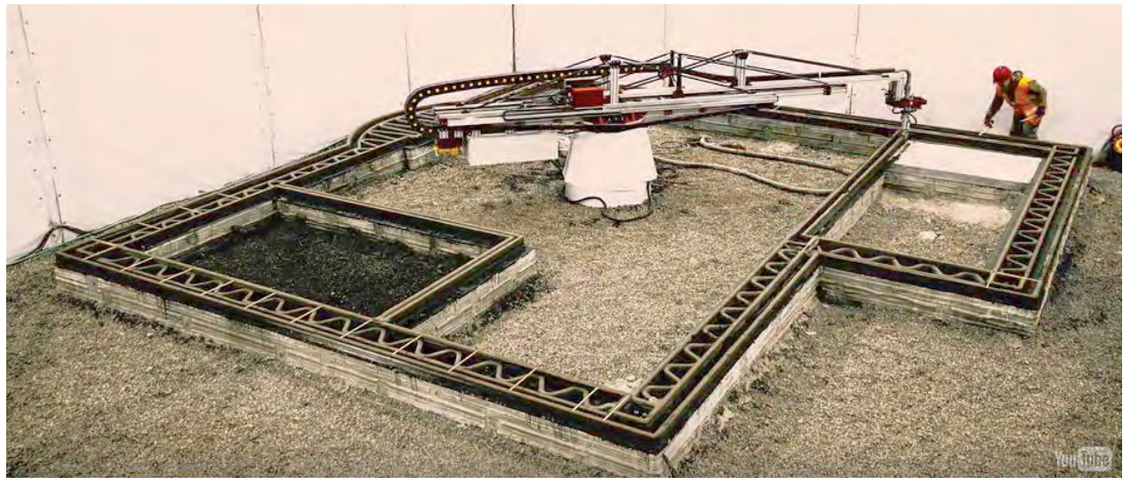
www.nu-core.com.cn



Renca
Russia

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

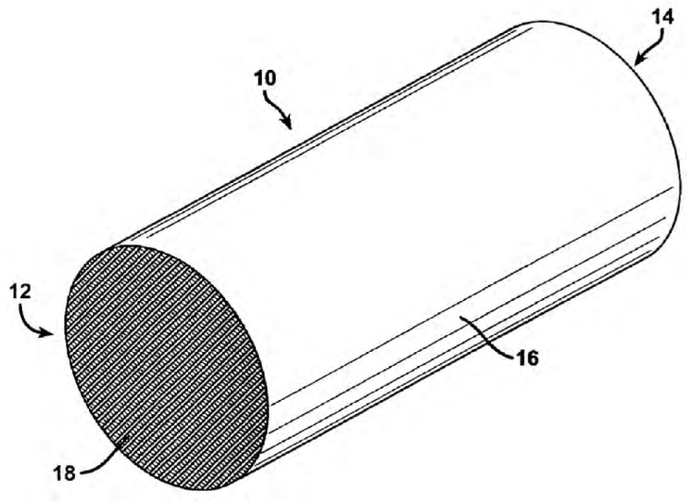
www.renca.com



Corning
USA

Patent US 7745363
Geopolymer ceramic composites for high temperature

www.corning.com



Dow Chemical USA

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

www.dow.com

Orexo AB
Sweden

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

www.orexo.com

INOMAT
Germany

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

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

GeoPol
Czech Rep.

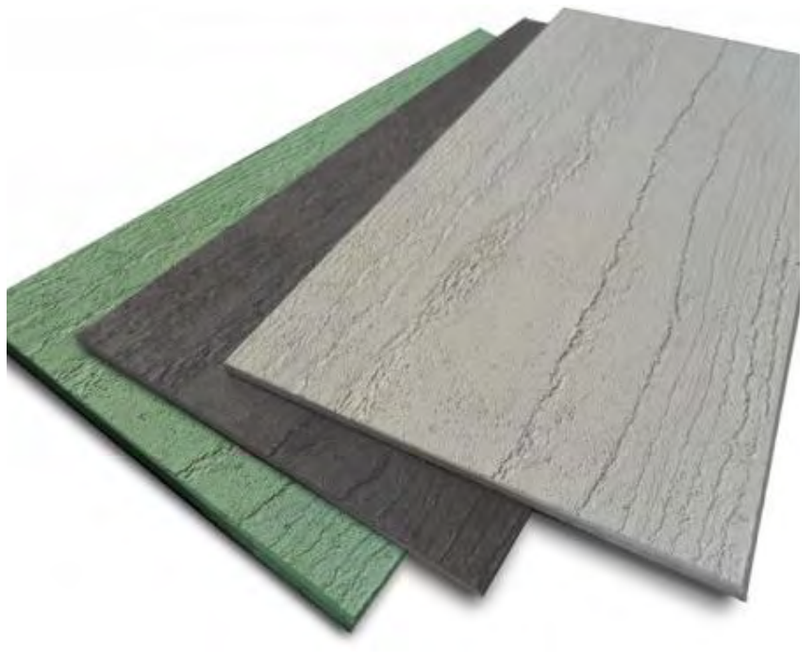
Geopolymer sand binder for cores in foundries

www.geopol-info.com

Nova Lignum Netherlands

Ceranex™
Geopolymer
composite sidings and
façade claddings

www.novalignum.nl



NanoVoltaics Inc. USA

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

www.nanovoltaics.com

Allied Foam Tech Corp. USA

GeoFoam: geopolymer foam cement, for lightweight and fireproof applications

www.alliedfoamtech.com

Woellner
Germany

GEOSIL®
Ready to use alkali
silicates for Geopolymers

www.woellner.de

Vodnis Klo
Czech Rep.

Desil AI™
Geopolymer binder
system for foundries

www.vodnisklo.cz

PolyRap Canada

Econcrete: geopolymer concrete made out of mine tailings

www.polyrap.net

Argio Belgium

ArgioBricks: LTGS bricks (low temperature geopolymer setting)

www.argio.com

Brabant flamand, Meise.
Architecte : **Maarten Martens**
+ 25 logements, 2.500 m2 de maçonnerie Argio apparentes.

Reinforced Concrete Pipes Australia

eCP: geopolymer concrete pipes

www.rcpa.com.au

Watershed Materials USA

high strength masonry with a low carbon footprint using natural mineral based geopolymers.

www.watershedmaterials.com

Bowers Industrial USA

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

www.bowersindustrial.com

Aquaminerals Finlands

Solutions for water purification with patented geopolymer nitrogen removal adsorbents

www.aquaminerals.fi

AQUAMINERALS

Amec Foster Wheeler United Kingdom

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

www.amecfw.com

Lucideon United Kingdom

MIDAR: encapsulation, immobilisation of high hazard nuclear and chemical wastes

www.lucideon.com

Wincrete Brazil

Decorative architectural geopolymer binder panels for inside and outside

www.winblok.com.br

Néoterre France

Geobiology applications

www.neoterre.com

State of the Geopolymer R&D 2019

1) Geopolymer and archaeology

2) Geopolymer technologies

3) Geopolymer science

4) Geopolymer Cements / Concretes

Geopolymer research 1988

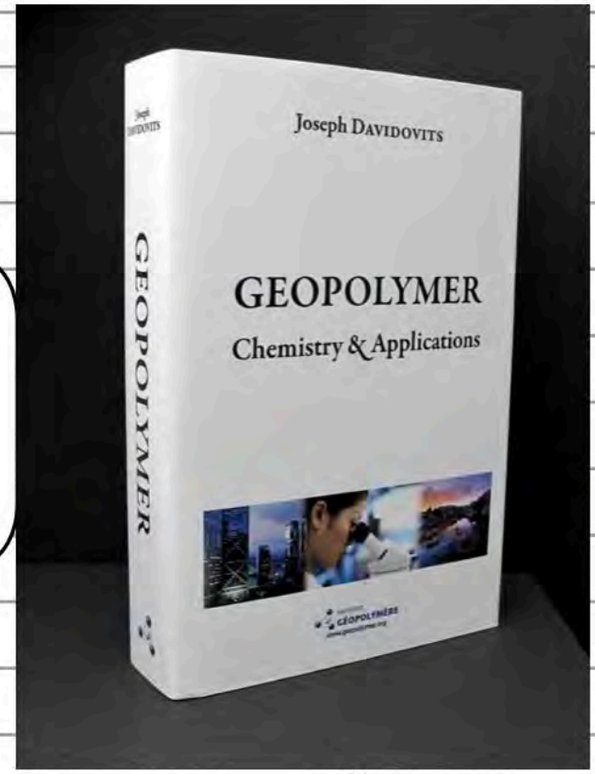
1st Geopolymer conference

Geopolymer research 2018

Scientific papers published per year

peer reviewed

keyword "geopolymer"



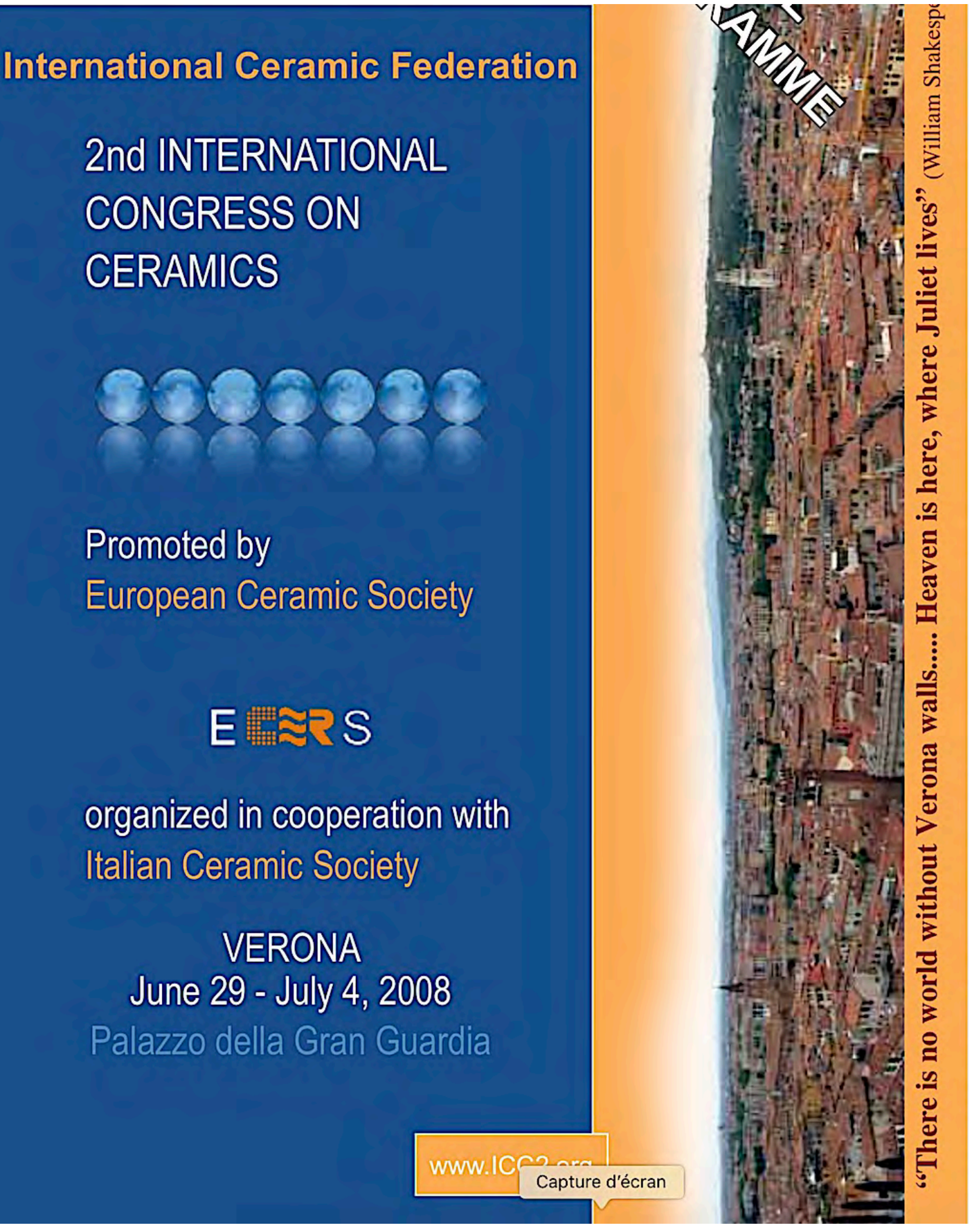
2013

1991

Year

440 420 400 380 360 340 320 300 280 260 240 220 200 180 160 140 120 100 80 60 40 20 0

1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013



Road map R&D presented at *2nd International Congress on Ceramics*, Verona, Italy, July 4th, 2008.

16 research topics

#1 Polymeric character of geopolymers

#2 Poly(siloxonate), soluble silicate (water-glass)

#3 Metakaolin MK-750-based geopolymer

#4 Calcium-based geopolymer

#5 Rock-based geopolymer

#6 Silica-based geopolymer

#7 Fly ash-based geopolymer

#8 Phosphate-based geopolymer

16 research topics

#9 Organic-mineral geopolymer.

#10 Long-term durability.

#11 Geopolymer-fiber composites.

#12 Geopolymer in ceramic processing.

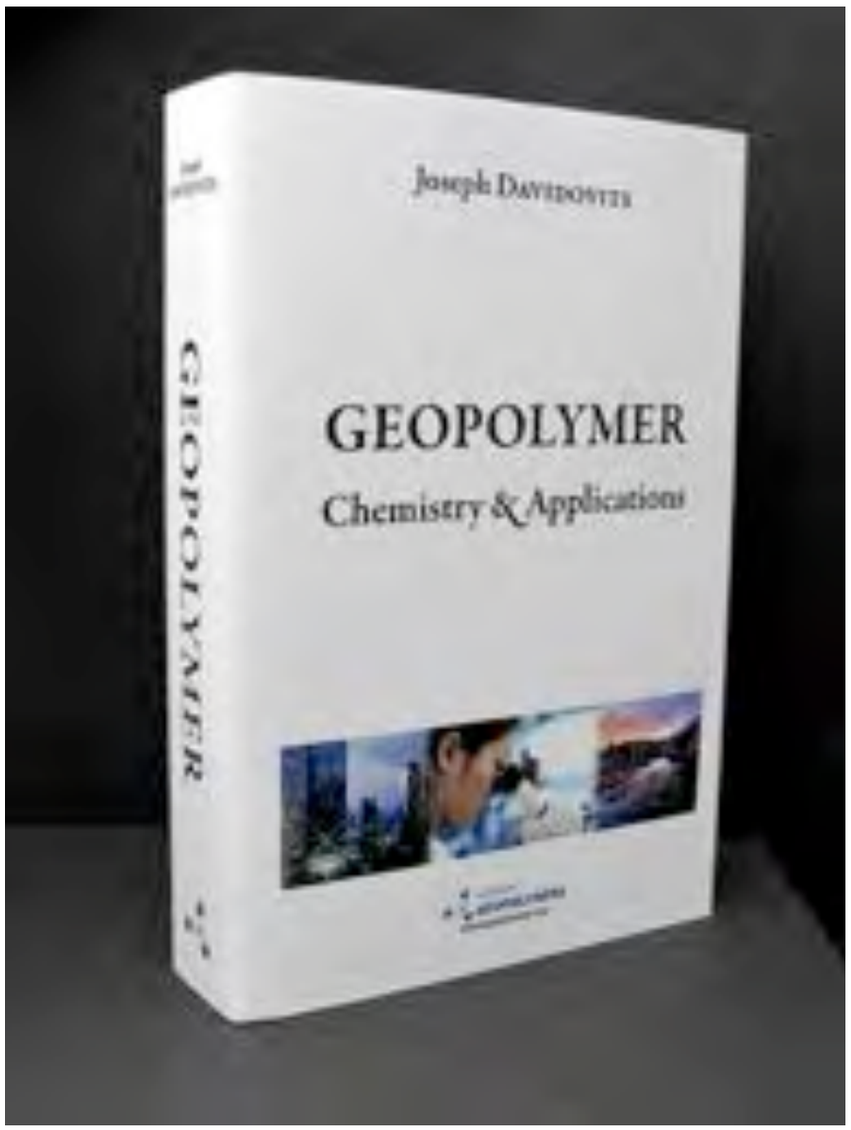
#13 The manufacture of geopolymer cements.

#14 Geopolymer concrete.

#15 Material for Radioactive waste, Particules and gaz pollution.

16 3D printing.

#1 Polymeric character of geopolymers



Chapter 2

Available for free download at

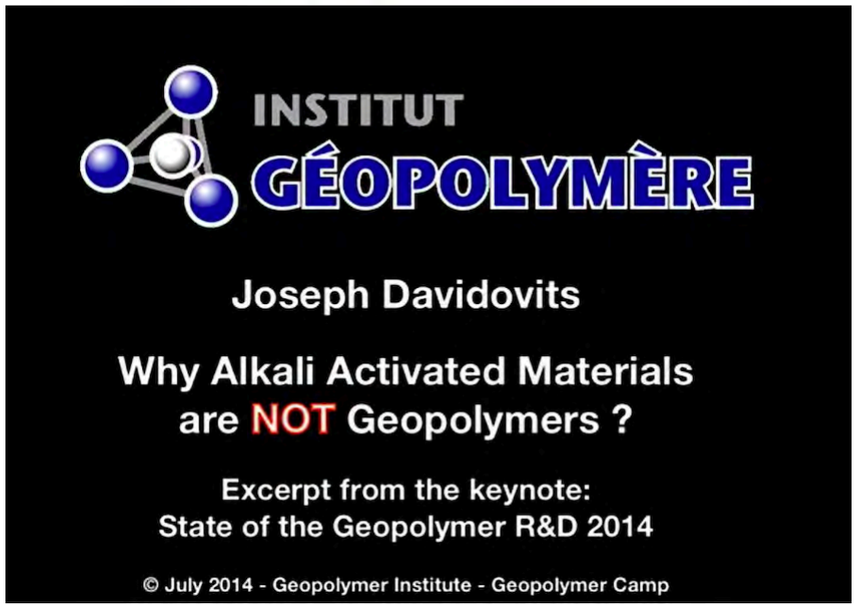
www.geopolymer.org

2016 GEOPOLYMERCAMP

10 Videos: State of the Geopolymer R&D

15 Videos: Special Keynotes

12 Videos: Lectures Spring 2014 and Spring 2016



4 Videos: Why Alkali Activated Materials are NOT Geopolymers?

GP-Institute > 17,100

YouTube > 9,500

Google Scholar

J. Davidovits

Emeritus Professor, Geopolymer Institute, 02100 Saint-Quentin, France
Verified email at geopolymer.org - Homepage
geopolymer chemistry and … ancient technologies

FOLLOW

TITLE	CITED BY	YEAR
Geopolymers: inorganic polymeric new materials J Davidovits Journal of Thermal Analysis and calorimetry 37 (8), 1633-1656	2660	1991
Geopolymer chemistry and applications J Davidovits Geopolymer Institute	1504	2008
Properties of geopolymer cements J Davidovits First international conference on alkaline cements and concretes 1, 131-149	705	1994
Chemistry of geopolymeric systems, terminology J Davidovits Geopolymer 99 (292), 9-39	638	1999
Geopolymers and geopolymeric materials J Davidovits Journal of Thermal Analysis and Calorimetry 35 (2), 429-441	551	1989
Global warming impact on the cement and aggregates industries J Davidovits World resource review 6 (2), 263-27	373	1994

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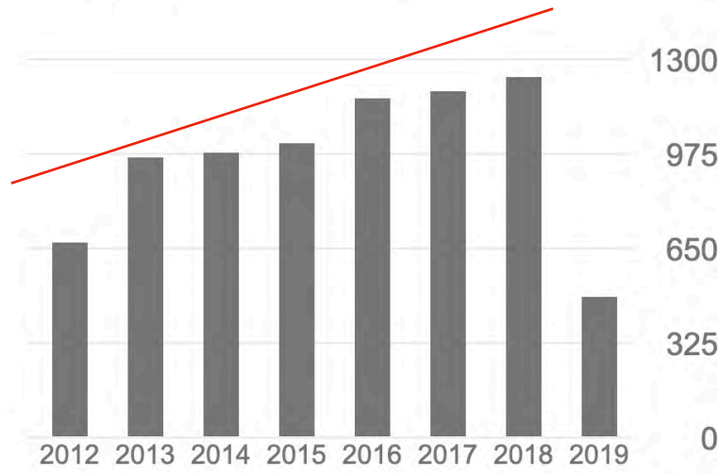
Cited by 15-05-2019 VIEW ALL

	All	Since 2014
Citations	11761	6069
h-index	39	28
i10-index	58	44

11,761



Co-authors EDIT

No co-authors

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Technical papers

26 pdf

Archaeological papers

9 pdf

Category: Technical papers

Papers dealing with geopolymer science and applications

#26 Standardized Method in Testing Commercial Metakaolins for Geopolymer Formulations.

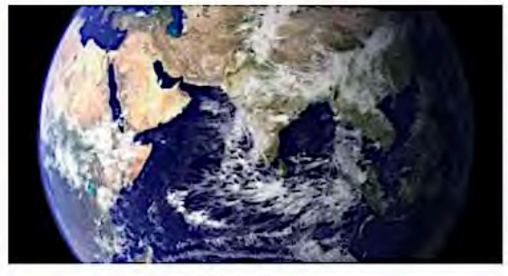
5 Mar 2019

Technical Paper #26 published May 2019: DOI: 10.13140/RG.2.2.18109.10727/1 Standardized Method in Testing...

25 Why Alkali-activated-materials AAM are not Geopolymers

30 Nov 2018

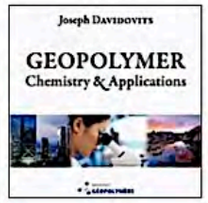
Technical paper # 25 published November 2018: DOI: 10.13140/RG.2.2.34337.25441 Why Alkali-activated-materials AAM...



24 False CO2 Values Published in Scientific Papers

Capture d'écran

#23 Technical Paper on Geopolymer Aircraft Pavement



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11th Geopolymer Camp and Tutorial

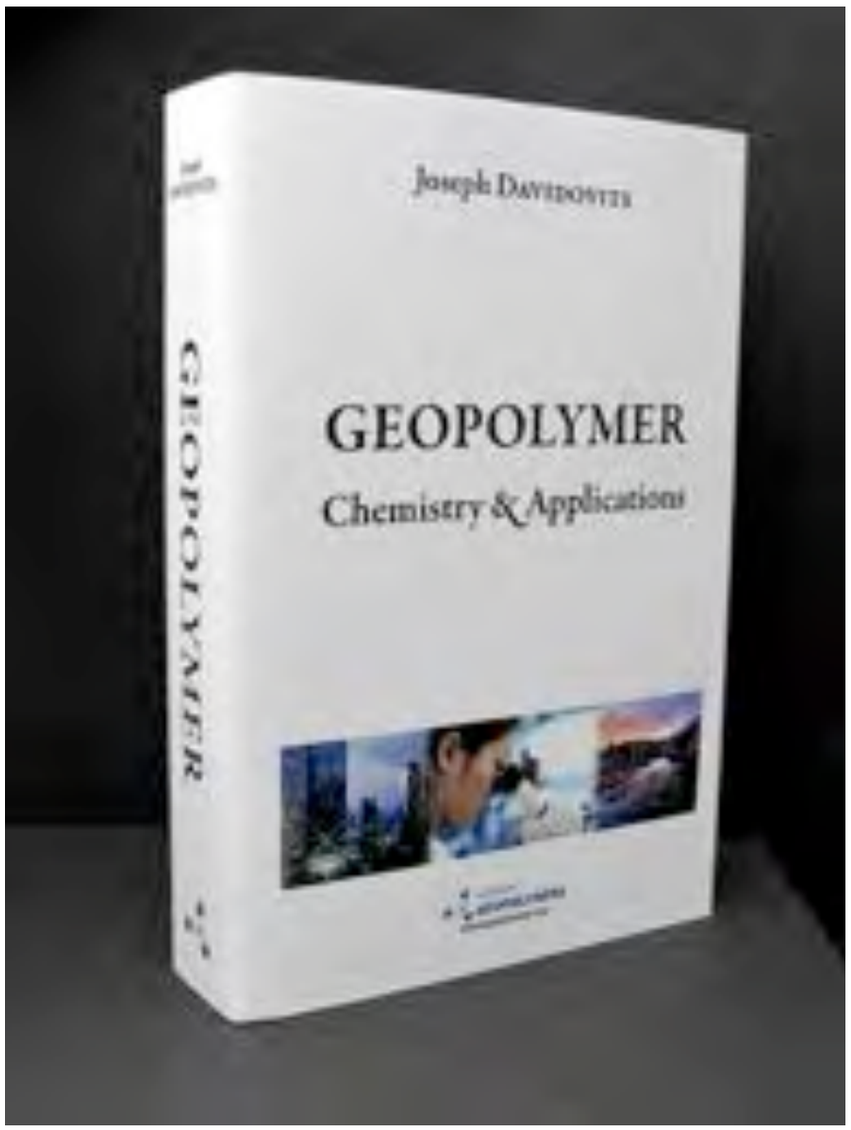
6 Mar 2019

#26 Standardized Method in Testing Commercial Metakaolins for Geopolymer Formulations.

5 Mar 2019

Tiahuanaco Monuments (Tiwanaku / Pumapunku), Bolivia are made of geopolymer artificial stones created 1400 years ago.

#3 Metakaolin MK-750-based geopolymer



Chapter 8

Geopolymer Institute Library

INSTITUT GÉOPOLYMÈRE

Technical Paper #26-MK-testing
May, 2019
https://www.geopolymer.org/category/library/technical-papers/

How to cite this paper:
Ralph Davidovits, Christine Pelegris, Joseph Davidovits, (2019), Standardized Method in Testing Commercial Metakaolins for Geopolymer Formulations, *Technical Paper #26-MK-testing,* Geopolymer Institute Library, www.geopolymer.org. DOI: 10.13140/RG.2.2.18109.10727/1

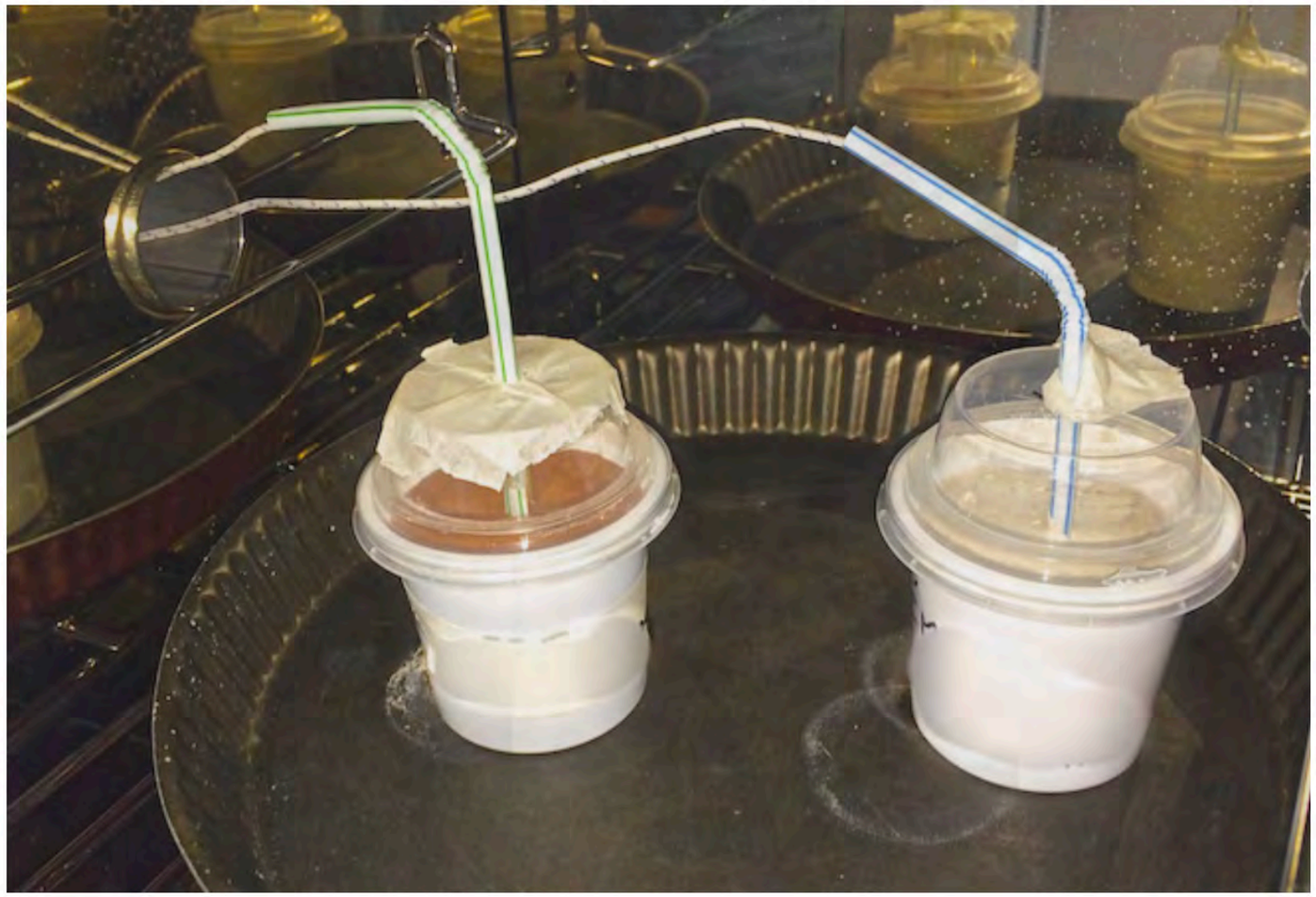
Standardized Method in Testing Commercial Metakaolins for Geopolymer Formulations.

Ralph Davidovits [a,b], Christine Pelegris [a] and Joseph Davidovits [b*]

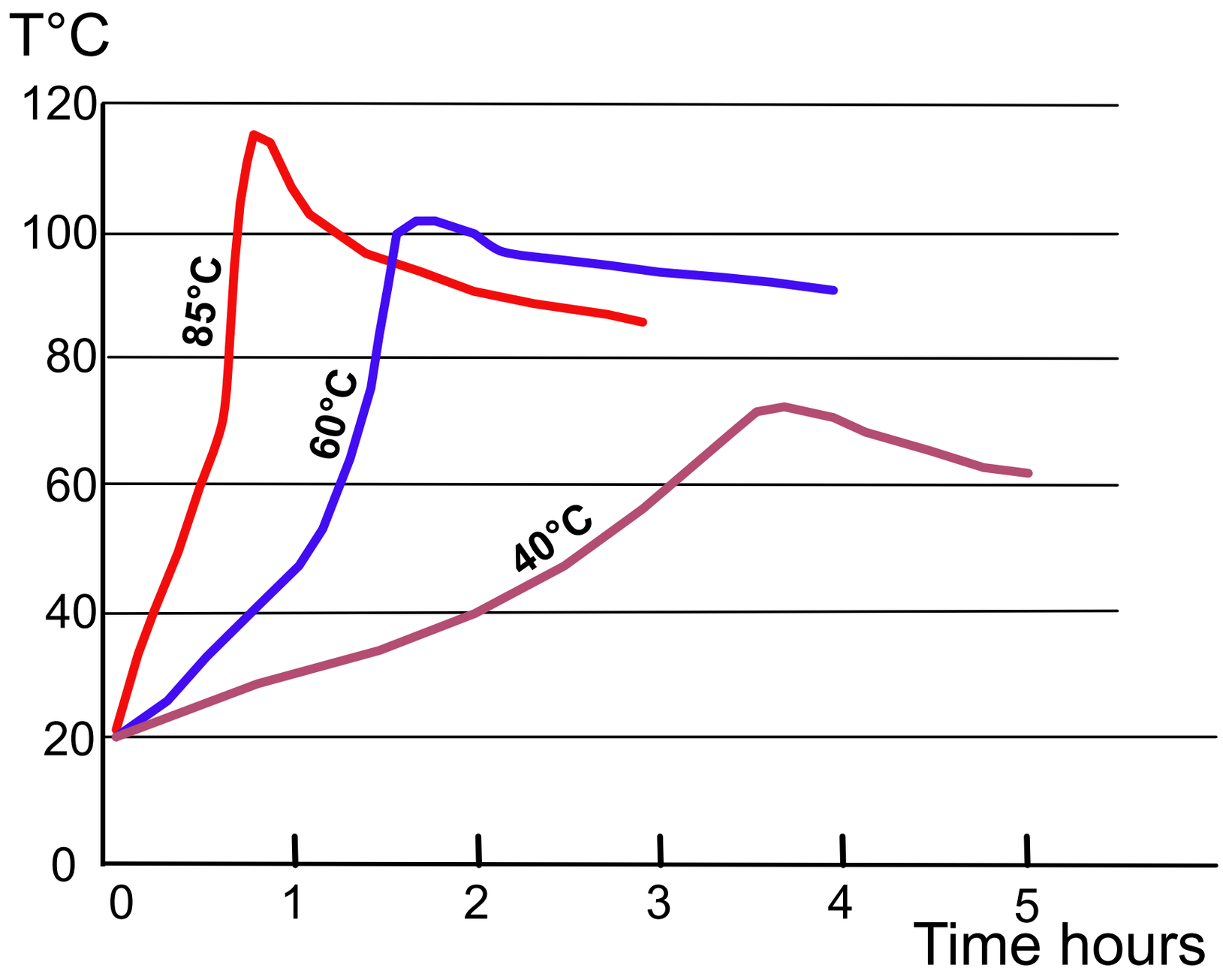
[a] Matériaux Avancés en Géopolymère, LTI - Université de Picardie Jules Verne, 02100 Saint-Quentin, France.
[b] Geopolymer Institute, 02100 Saint-Quentin, France.

Reactivity test, observing exothermicity

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

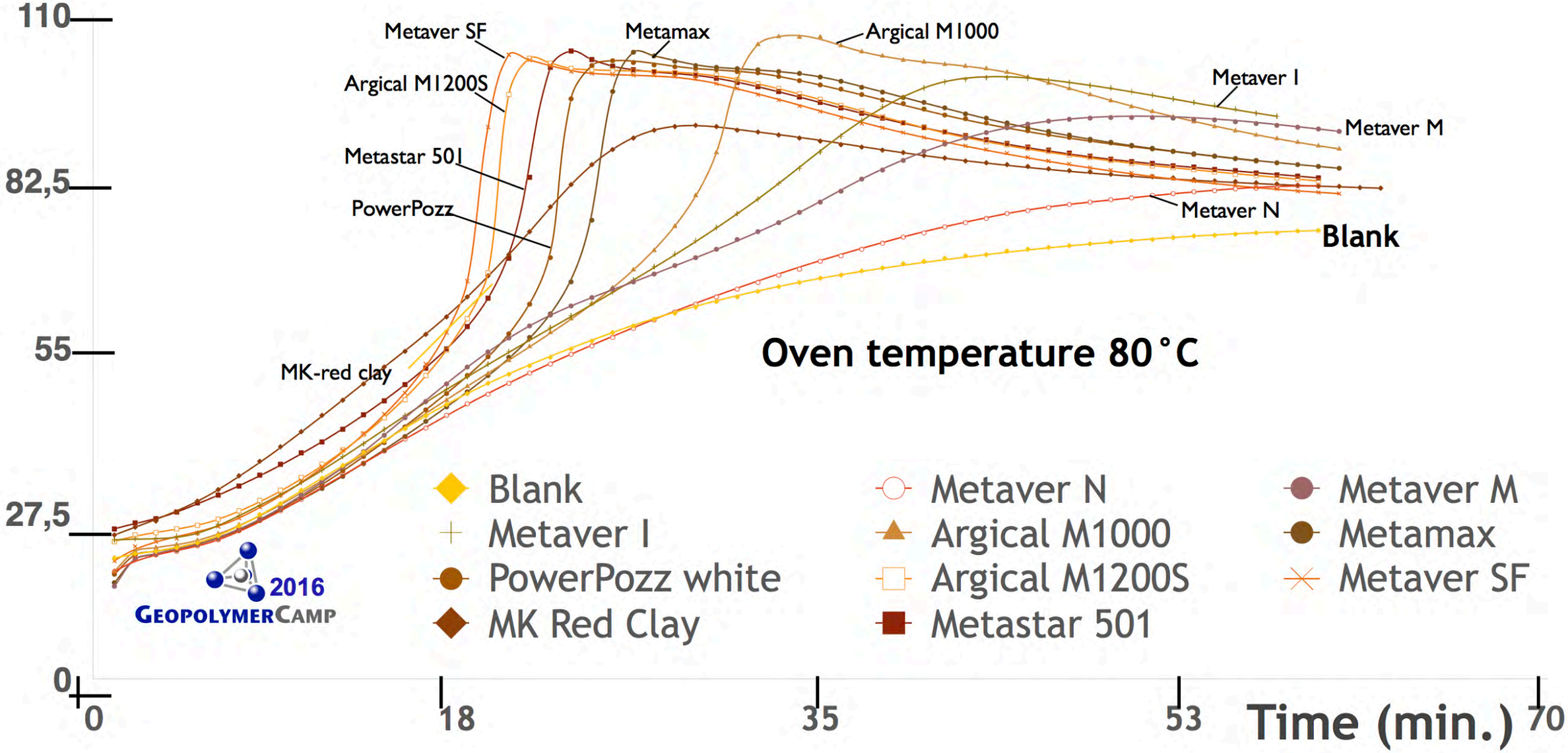


Exothermic polycondensation of MK-750-based geopolymer binder K-PSS at different curing temperatures

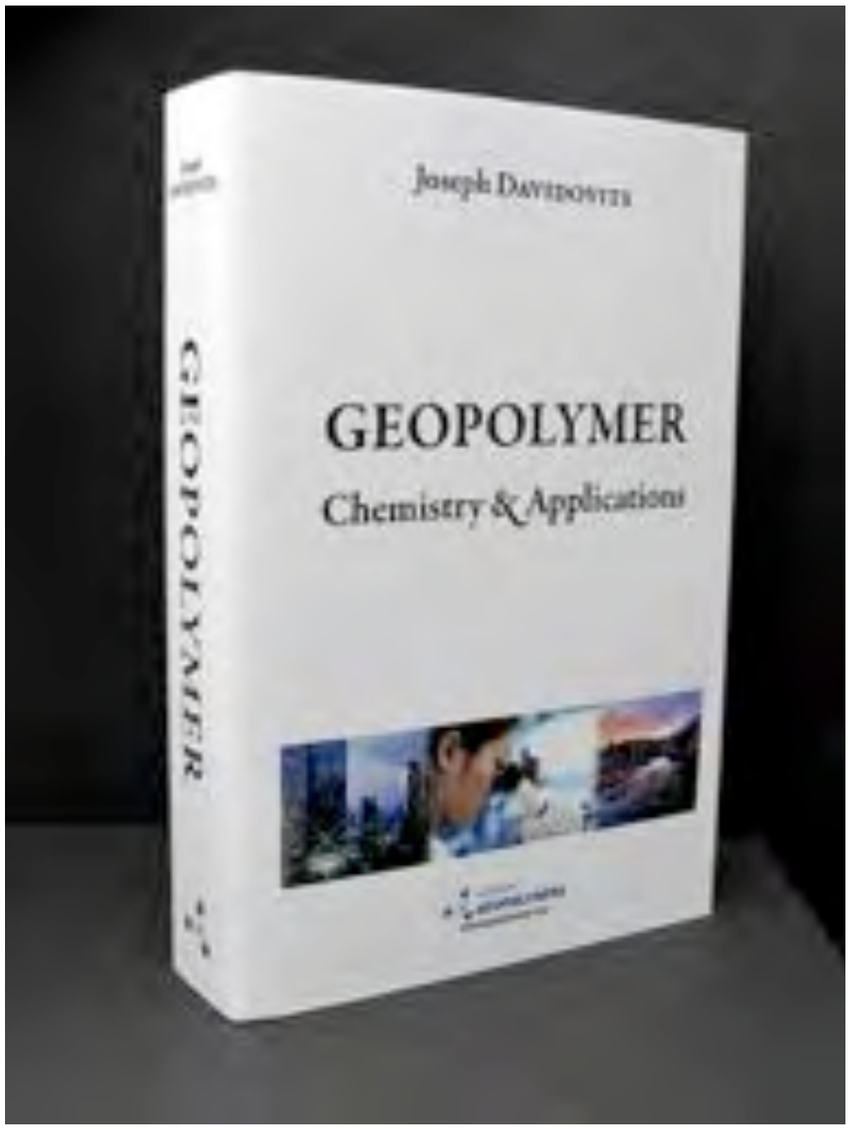


Testing of 10 commercial metakaolins

Exothermicity, reactivity

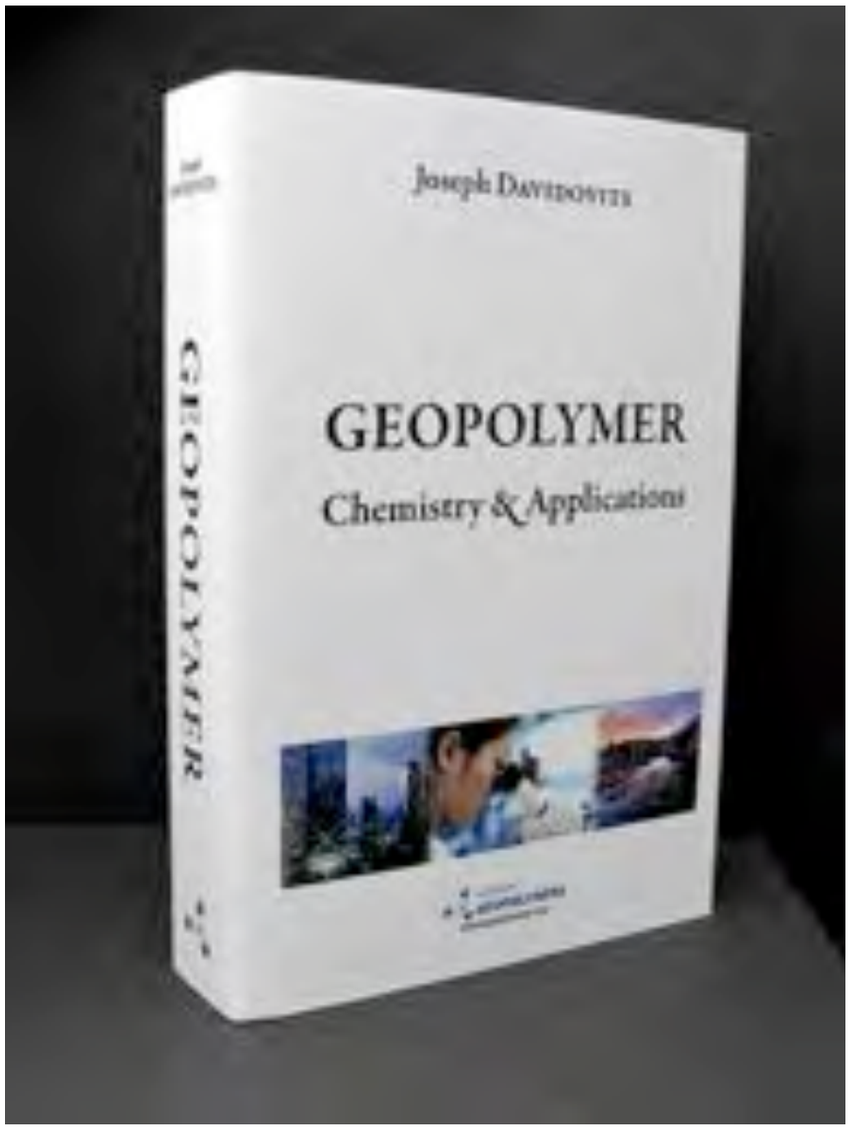


#10 Long-term durability, archaeological analogues.



Chapter 17

#15 Material for Radioactive waste, Particules and gaz pollution.



Chapter 17

Contents lists available at ScienceDirect

Journal of Environmental Management 2019

journal homepage: www.elsevier.com/locate/jenvman

Geopolymer technology for the solidification of simulated ion exchange resins with radionuclides

Wei-Hao Lee[a,*], Ta-Wui Cheng[a], Yung-Chin Ding[a], Kae-Long Lin[b], Shih-Wei Tsao[a], Chun-Ping Huang[c]

In this study, geopolymer was applied to convert ion exchange resins contaminated with radionuclides into a solid waste form.

Geopolymer has superior properties to enable the encapsulation of spent resins.

(……) The *International Atomic Energy Agency* has reported that geopolymer can be used for the stabilization of radioactive waste with a geopolymer cement matrix and provides excellent leach resistance (IAEA, 2013). Therefore, slag-based geopolymers were studied for the purpose of spent resin solidification in this study.

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

2019

A porous gradient geopolymer-based tube membrane with high PM removal rate for air pollution

Jie-ting Wang, Yuan-yuan Ge, Yan He, Meng-xue Xu, Xue-min Cui*

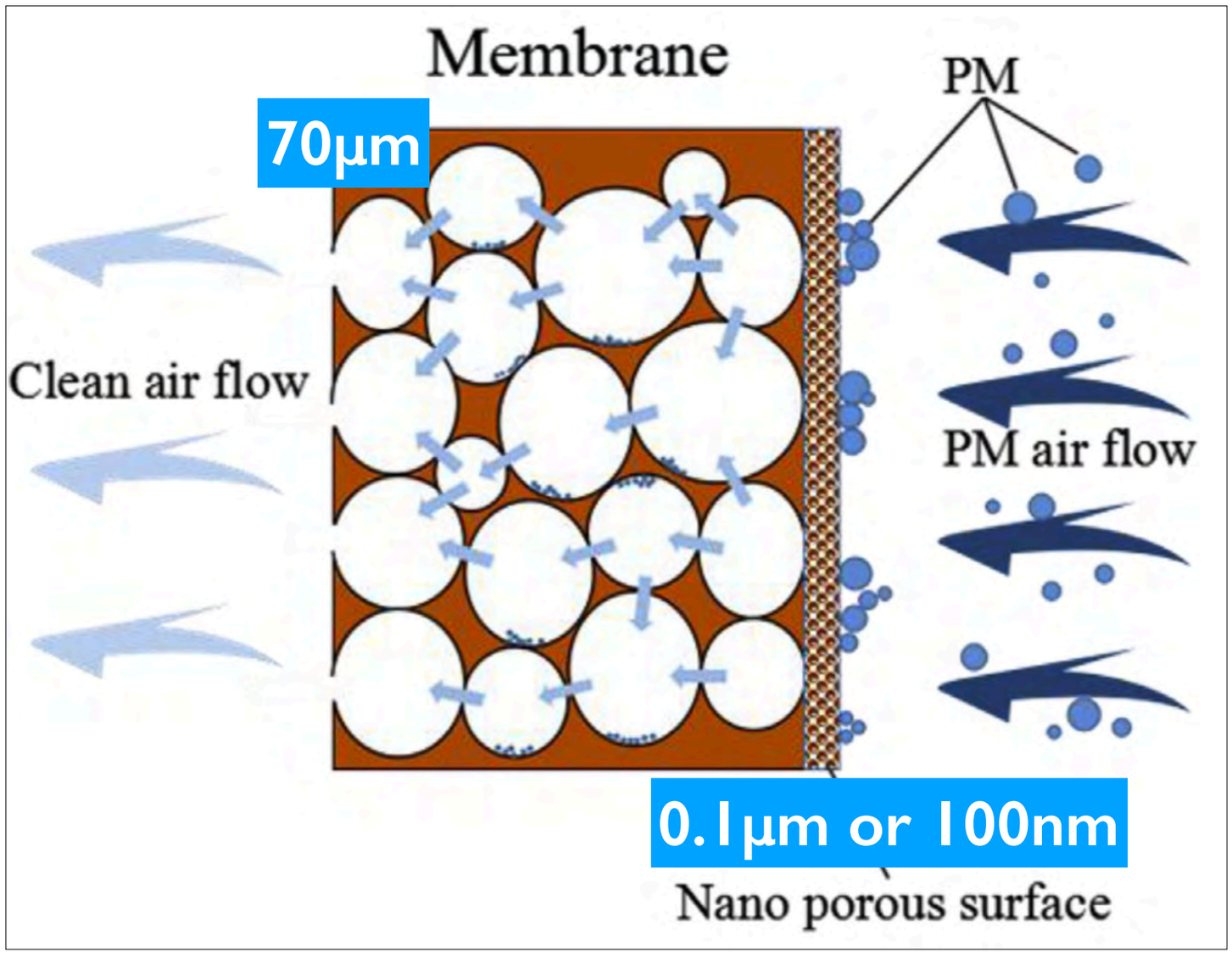
Existing technology does not meet the urgent need for a cheap and efficient carbon particulate matter (PM) (particle sizes below 10-2.5 nm) removal filter.

A porous gradient geopolymer-based tube membrane was successfully prepared using one-step molding.

Many diseases and conditions have been reported to be associated with PM pollution, including lung cancer, asthma, morbidity and mortality. Recently, people in developing countries such as China have suffered from serious PM.

The innovative porous gradient tube membrane for PM removal was fabricated by *metakaolin based geopolymers with* a 70μm porous membrane body and 0.1μm or100 nm nanoporous surface (Figure). The porous gradient geopolymer-based tube membrane has a compressive strength of 3.9MPa and a pressure drop of 0.01 MPa.

In PM filtration the removal efficiency reached 98.5% to 99.3%, showing great potential for geopolymer in PM removal filtration.



State of the Geopolymer R&D 2019

1) Geopolymer and archaeology

2) Geopolymer technologies

3) Geopolymer science

4) Geopolymer Cements / Concretes

United States Patent [19]

Davidovits et al.

[11] **Patent Number: 4,509,985**

[45] **Date of Patent: Apr. 9, 1985**

[54] **EARLY HIGH-STRENGTH MINERAL POLYMER**

[75] Inventors: **Joseph Davidovits**, Saint-Quentin, France; **James L. Sawyer**, Friendswood, Tex.

[73] Assignee: **Pyrament Inc.**, Houston, Tex.

[21] Appl. No.: **582,279**

[22] Filed: **Feb. 22, 1984**

1984

[51] **Int. Cl.**[3] **C04B 19/04**

[52] **U.S. Cl.** **106/84**; 106/85; 106/117

[58] **Field of Search** 106/84, 85, 117

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,349,386 9/1982 Davidovits 106/85

Primary Examiner—James Poer
Attorney, Agent, or Firm—McAulay, Fields, Fisher, Goldstein & Nissen

[57] **ABSTRACT**

An early high-strength mineral polymer composition is formed of a polysialatesiloxo material obtained by adding a reactant mixture consisting of alumino-silicate oxide (Si_2O_5,Al_2O_2) with the aluminum cation in a four-fold coordination, strong alkalis such as sodium hydroxide and/or potassium hydroxide, water, and a sodium/-potassium polysilicate solution; and from 15 to 26 parts, by weight, based upon the reactive mixture of the polysialatesiloxo polymer of ground blast furnace slag. Sufficient hardening for demolding is obtained in about 1 hour with this composition.

6 Claims, No Drawings

1984

Slag / MK-based geopolymer cement

1997

Slag / Rock-based geopolymer cement

2006

Slag / FA-based geopolymer cement

2010

Slag / Ferro-based geopolymer cement

TECHNICAL PAPER

GEOPOLYMERE

Geopolymer Institute

1994

☞ **Gold Ribbon Award**

for the most significant real advances in materials research of the last decade

REAL ADVANCES IN MATERIALS

A Symposium

Recognizing the most significant research in materials leading to new technologies with potential impact on society.

September 26, 1994

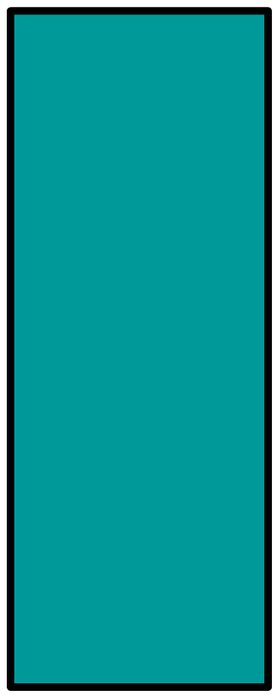
The National Press Club
Washington, DC

Program

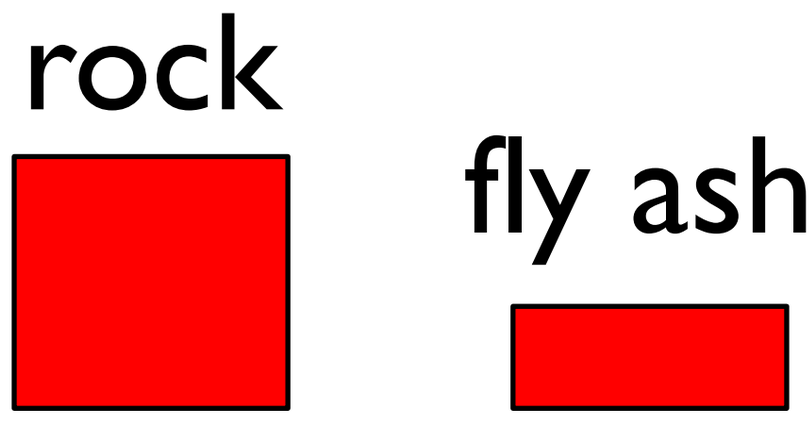
NASTS
National Association for Science, Technology and Society

with the cooperation of
the Federation of Materials Societies
and the support of
the Okinaga Foundation

Low-energy cement
Mega Joule / 1 tonne



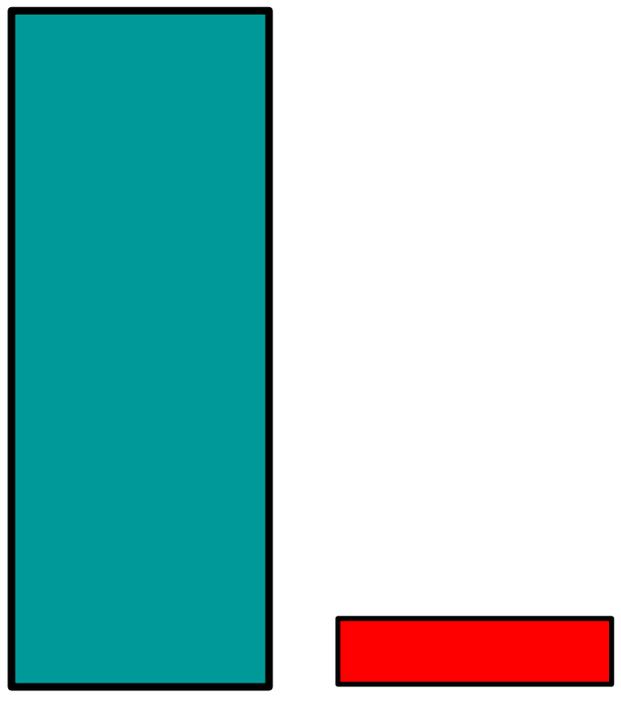
Portland
4700 MJ



Geopolymer
1960 to 775 MJ,
reduction 60 to 84%

Low-CO_2 cement
CO_2 emission / 1 tonne

Portland
0.85 tonne



Geopolymer
0,1 to 0,15
tonne
reduction
80-90%

False CO_2 Emission values for Geopolymer cements / concretes

published in Scientific Papers

GEOPOLYMER
INSTITUTE

24 False CO2 Values Published in Scientific Papers

7 Dec 2015

Technical paper #24

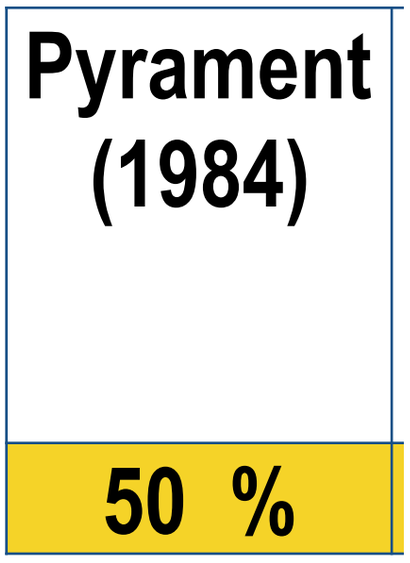
False Values on CO_2 Emission for Geopolymer Cement/Concrete Published in Scientific Papers

*Adapted from the article originally published in Elsevier's internet site "**Materials Today**" at Environmental Implications of Geopolymers, 29 June 2015. See also the presentation at the Geopolymer Camp 2015.* See also the news Virtual Journal on Geopolymer Science .

(K-Ca) geopolymer cements.

Evolution since 1983-85.

K-silicate % by weight



(K-Ca) geopolymer cements.

Evolution since 1983-85.

K-silicate % by weight

Pyrament (1984)	Geopolymite 50 (1987)
50 %	50 %

(K-Ca) geopolymer cements.

Evolution since 1983-85.

K-silicate % by weight

Pyrament (1984)	Geopolymite 50 (1987)	Rock-based (1997) 100 MPa
50 %	50 %	20 %

(K-Ca) geopolymer cements.

Evolution since 1983-85.

K-silicate % by weight

Pyrament (1984)	Geopolymite 50 (1987)	Rock-based (1997) 100 MPa	Rock-based (2002) 50 MPa
50 %	50 %	20 %	17 %

(K-Ca) geopolymer cements.

Evolution since 1983-85.

K-silicate % by weight

Pyrament (1984)	Geopolymite 50 (1987)	Rock-based (1997) 100 MPa	Rock-based (2002) 50 MPa	Fly Ash-based (2006) 100 MPa
50 %	50 %	20 %	17 %	14 %

(K-Ca) geopolymer cements.

Evolution since 1983-85.

K-silicate % by weight

Pyrament (1984)	Geopolymite 50 (1987)	Rock-based (1997) 100 MPa	Rock-based (2002) 50 MPa	Fly Ash-based (2006) 100 MPa	Fly Ash-based (2006) 40 MPa
50 %	50 %	20 %	17 %	14 %	10 %

Poly(sialate-siloxo) geopolymer concrete

2013

UNIVERSITY OF QUEENSLAND GLOBAL CHANGE INSTITUTE

Brisbane, Australia

Toowoomba-Brisbane-West Wellcamp Airport, by

WAGNERS, Australia

2014

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

2017

Eco-efficient cements: Potential economically viable solutions for a low-CO_2 cement-based materials industry

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Final remarks

Geopolymer materials produced with fly ash and blast furnace slag have low CO2 footprint, ***but their mitigation potential is dubious*** [suspicious - unreliable] ***since they will mostly divert slag and fly ash from Portland cement.***

Several suppliers for metakaolin MK-750

Supplier of Blast Furnace Slag

2003 - 2010

ARCELOR-MITTAL France

geopolymer precursor Blast Furnace Slag GGBS.

ECOCEM France, and other companies:

in Europe: ECOCEM Ireland, ORCEM Netherlands,

in USA ORCEM USA

Geopolymer cement/concrete

Technical parameters studied and solved

- Adjuvants, plasticizers, water reducers.
- Retarder.
- Drying-shrinkage.
- ***User-friendly*** One-part GP-cement.

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2013

GEOPOLYMER CEMENT

a review

by

Professor Joseph Davidovits

January 2013

Geopolymer Library download: > 4,360

The 2012 State of the Geopolymer R&D, suggested to select two categories, namely:

- *Slag/fly ash-based geopolymer cement*: fly ashes are available in the major emerging countries;
- *Ferro-sialate-based geopolymer cement* (*similar to rock-based*): this geological iron rich raw material is present in all countries through out the globe.

Ferro-sialate [Fe-O-Si-O-Al-O]

geopolymerisation of geological elements rich in iron oxides and ferro-kaolinite,

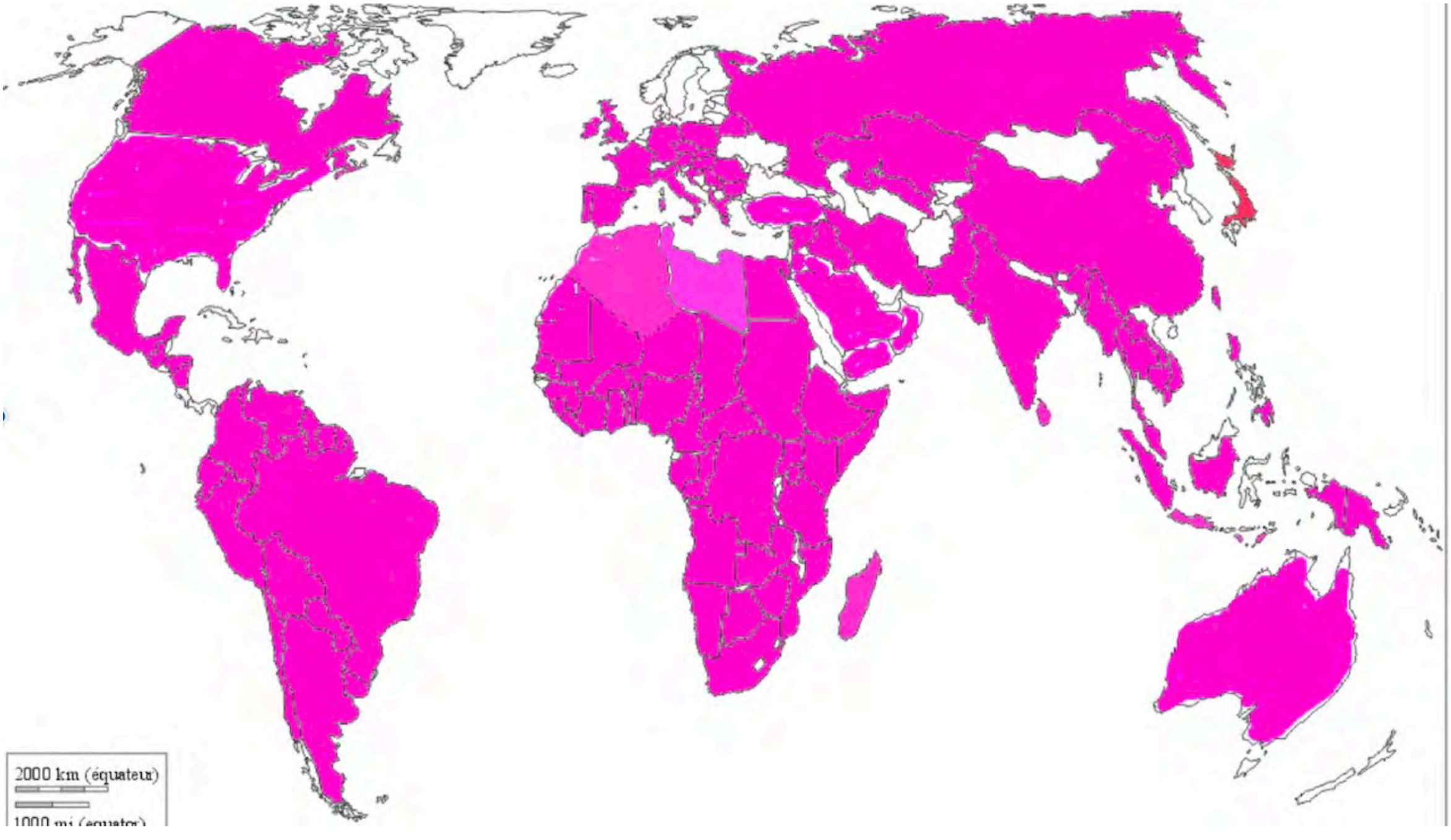
- formed in weathered acidic rocks :

sandstone, granite or gneiss,

- or in basic rocks (mafic) :

basalt and gabbro.

World-wide availability of raw material for ferro-sialate geopolymer cement



(Na,K,Ca)-(ferro-sialate)-based geopolymer cement

2019

GEOPOLYMERCAMP

State of the Geopolymer R&D 2019

Joseph Davidovits

INSTITUT GÉOPOLYMÈRE

UNIVERSITÉ de Picardie Jules Verne — CAMPUS universitaire de Saint-Quentin — PÔLE TECHNOLOGIQUE

2019 GEOPOLYMERCAMP

11th GP-Camp

LTI PÔLE TECHNOLOGIQUE SAINT-QUENTIN — UNIVERSITÉ de Picardie Jules Verne — MAG Matériaux Avancés en Géopolymère

Saint-Quentin (France)

July 8-10, 2019