INSTITUT GÉOPOLYMÈRE

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

2021 GEOPOLYMERCAMP

13th GP-Camp

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

Saint-Quentin (France)

Aug. 30-31, Sep.1, 2021

Geopolymer research 1988

1st Geopolymer conference

Geopolymer research 2018

GEOPOLYMERCAMP 2021

State of the Geopolymer R&D 2021

Joseph Davidovits

State of the Geopolymer R&D

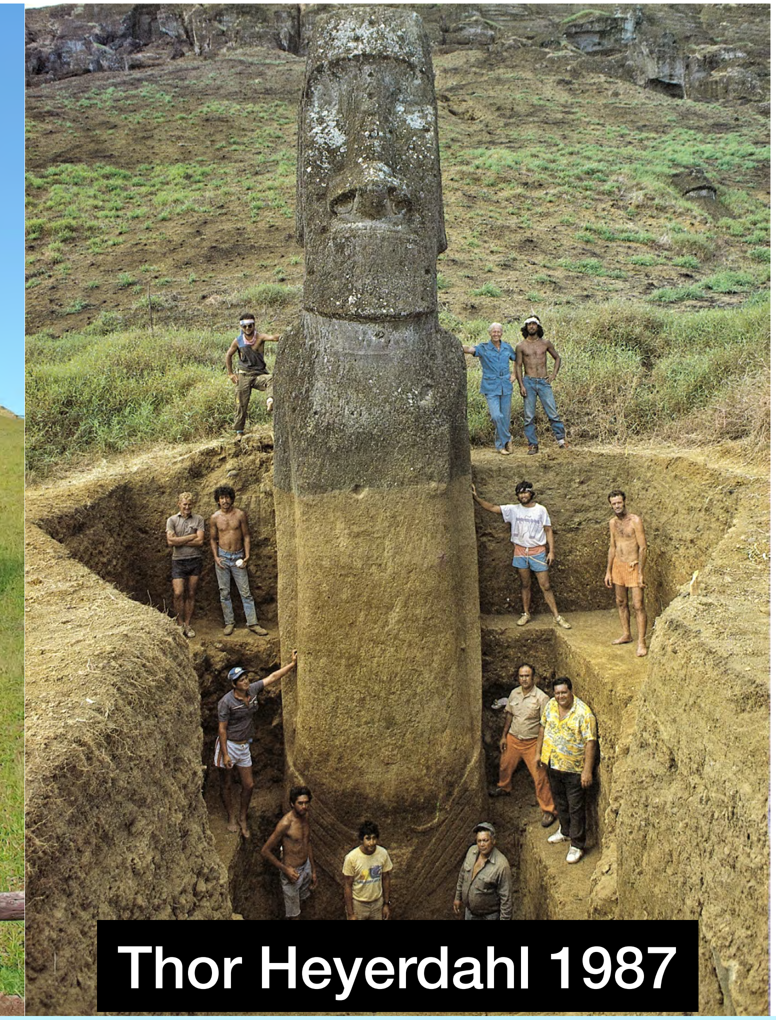
1) Geopolymer science
2) Geopolymer and Global warming.
3) Geopolymer and archaeology: South America (Tiwanaku/Pumapunku) and the relations with Easter Island : artificial geopolymer stone?

Easter Island

2016 Ralph Davidovits

Chemamülles

Rano Raraku volcano



Thor Heyerdahl 1987

Maoi Ahu Tongariki

State of the Geopolymer R&D 2021

1) Geopolymer science and Global warming

2) Geopolymer and archaeology: South America and Easter Island

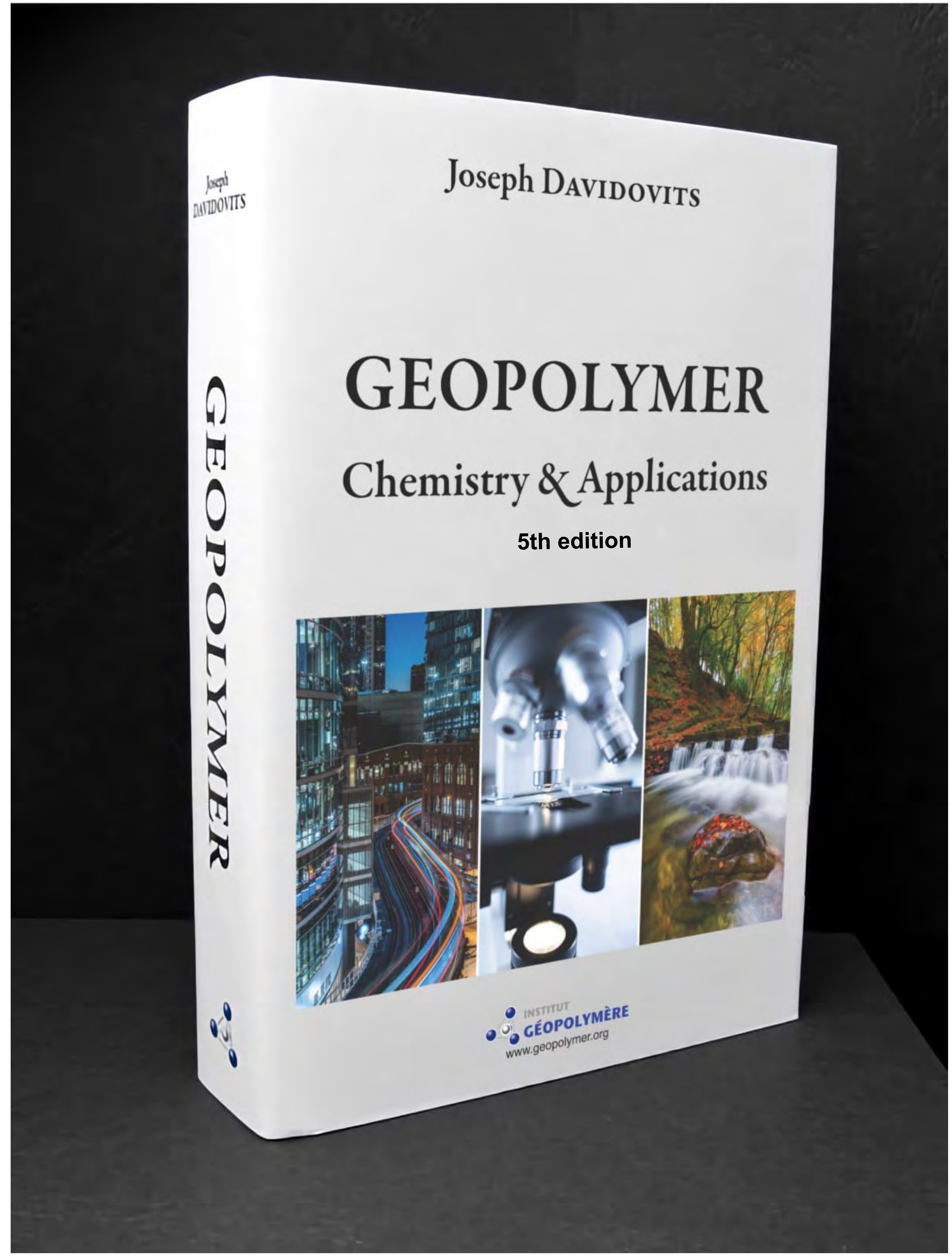
In addition to the numerous updates, this 5th edition adds two new chapters:

- Chap. 11: *Ferro-sialate Geopolymers*
- Chap. 21: *How to quantify and develop geopolymer formulas*.

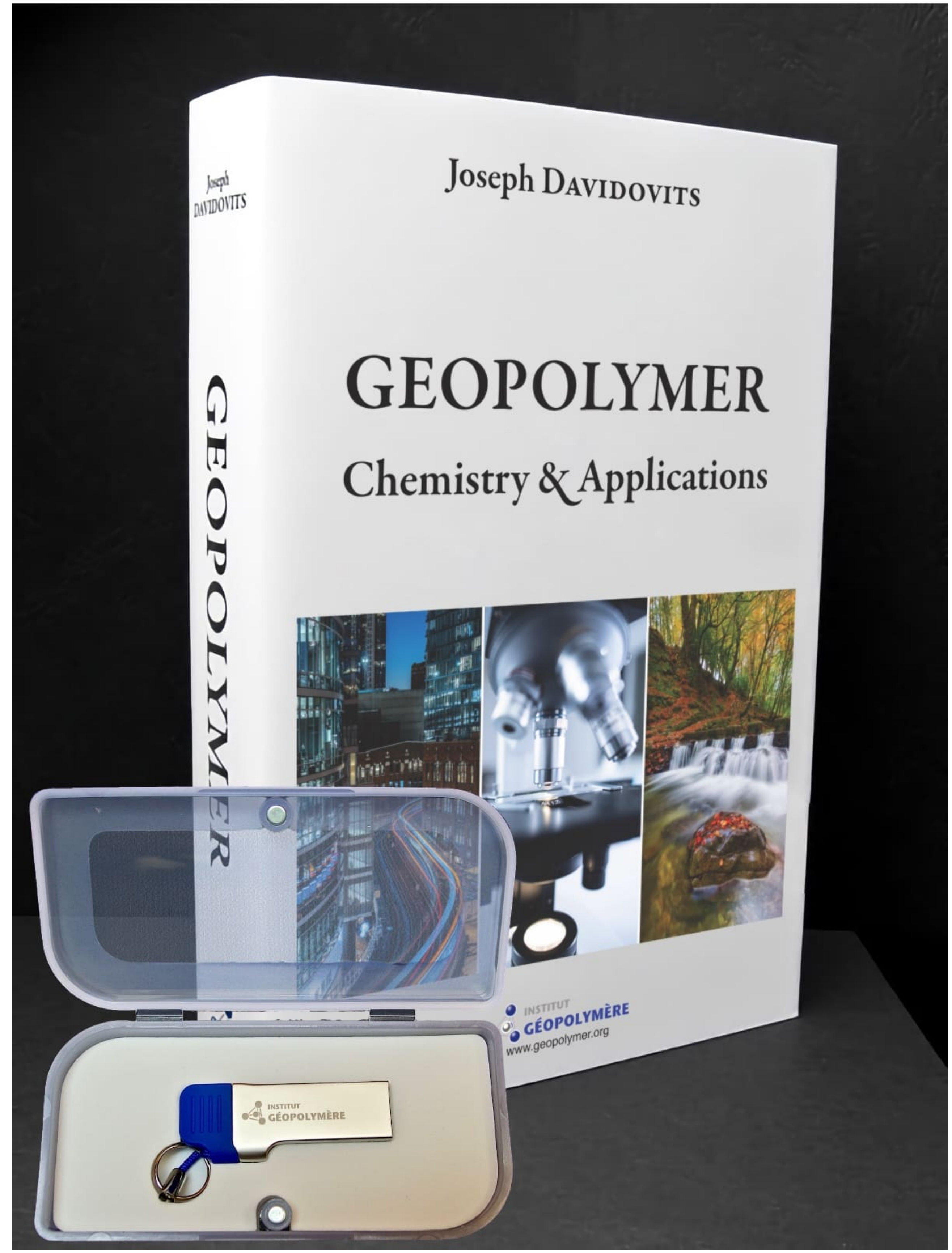
This last new chapter details

- How to select raw materials,
- How to calculate a formula,
- Description of the process method for optimal results,

all in a very pragmatic way.



We are now launching a new ***Geopolymer Bundle for Newcomers*** which replaces the former one. It includes an experimental part totalizing 3 hours of videos, taken during the Tutorial/Workshop of the Geopolymer Camp.



16 research topics

#1 Polymeric character of geopolymers

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

#3 MK-750-based Ferro-sialate 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: No fly ash !

#14 Geopolymer concrete.

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

16 3D printing.

#1 Need for standards

Computers and Concrete, *Vol. 24, No. 1*
DOI: https://doi.org/10.12989/cac.20

2019

Applied linear and nonlinear statistica
evaluating strength of Geopolymer

Prabhat Ranjan Prem*, A. Thirumalaiselvi[a] and I

CSIR-Structural Engineering Research Centre, Chenn

The applied statistical models studied are divided into three different categories - linear regression, tree regression and kernel methods (support vector regression (SVR), kernel ridge regression (KRR), Gaussian process regression (GPR), relevance vector machine (RVM)].

The performance of the methods is compared in terms of error indices, computational effort, convergence and residuals. Based on the present study, kernel based methods (GPR and KRR) are recommended for evaluating compressive strength of Geopolymer concrete.

Materia
Advanc

2020

ROYAL SOC
OF CHEMIS

Formulation of mix design for 3D geopolymers: a machine learning

Ali Bagheri *[a] and Christian Cremona[b]

This work evaluates the application of machine learning in the formulation of construction materials. The aim is to introduce a feasible approach to classify geopolymer samples made via additive manufacturing technique.

This study employs popular recursive- partitioning functions including rpart and ctree to build separate classification models being compared at the end. According to the findings, these functions demonstrate great ability to create classification models for 3D-printed geopolymers with up to 100% positive predictive value in ctree function and up to 81% positive predictive value in the rpart function.

Materia
Advanc

2020

ROYAL SOC
OF CHEMIS

Formulation of mix design for 3D
geopolymers: a machine learning

Ali Bagheri *[a] and Christian Cremona[b]

(…)

This study can be an excellent starting point for developing a guide/ standard that maps the 3D-printed boron-based geopolymer samples into categories based on compressive strength.

State of the Geopolymer R&D 2021

1) Geopolymer science

2)Global warming

3)Geopolymer and archaeology: South America and Easter Island

#2 Global warming

Photo credit: AP/Euronews (31/12/2019).

A continent is on fire. Both Australia and California have never experienced such an inferno. More and more citizens blame the climate change, CO_2 emissions responsible for this.

World Resource Review,
Vol. 6, No.2, pp. 263-278, 1994

Global Warming Impact on the Cement and Aggregates Industries
by Joseph Davidovits

Summary

(…)

The production of 1 tonne of cement directly generates 0.55 tonnes of chemical-CO_2 and requires the combustion of carbon-fuel to yield an additional 0.40 tonnes of CO_2. To simplify

1 T of cement = 1 T of CO2


World Resource Review

1994

GLOBAL WARMING AND THE EXTREME EVENT INDEX

THE IMPACT OF INTENSIVE FOREST MANAGEMENT ON CARBON STORES IN FOREST ECOSYSTEMS

INCREMENTALITY AND ADDITIONALITY: A NEW DIMENSION TO NORTH-SOUTH RESOURCE TRANSFERS?

NATIONAL ENVIRONMENTAL PLAN OF AUSTRIA

AN ANALYSIS OF HUMAN-INDUCED LAND TRANSFORMATIONS IN THE SAN FRANCISCO BAY/SACRAMENTO AREA

FEDERAL GOVERNMENT - PRIVATE SECTOR PARTNERSHIPS FOR ADDRESSING ENVIRONMENTAL CONCERN AND TECHNOLOGY DEVELOPMENT

INDUSTRIAL ENERGY EFFICIENCY AND GLOBAL WARMING

COMPARISON OF RADIATIVE FORCING IMPACTS OF THE USE OF WOOD, PEAT, AND FOSSIL FUELS

GLOBAL WARMING IMPACT ON THE CEMENT AND AGGREGATES INDUSTRIES

Overlooked by all experts, including United Nations Environment experts and myself.

Burning of 10 t Carbon (C=12 g/mol.) produces 36.66 t of CO_2 (CO_2 = 44 g/mol.). But the burning of coal generates 10% by weight of fly ash. In other words,

10 t coal is producing 1t fly ash and emits 33 t CO_2.

2020 GEOPOLYMERCAMP

GP-cement / OPC with 50/50 FA

***16.5 t of CO_2 emission*.**

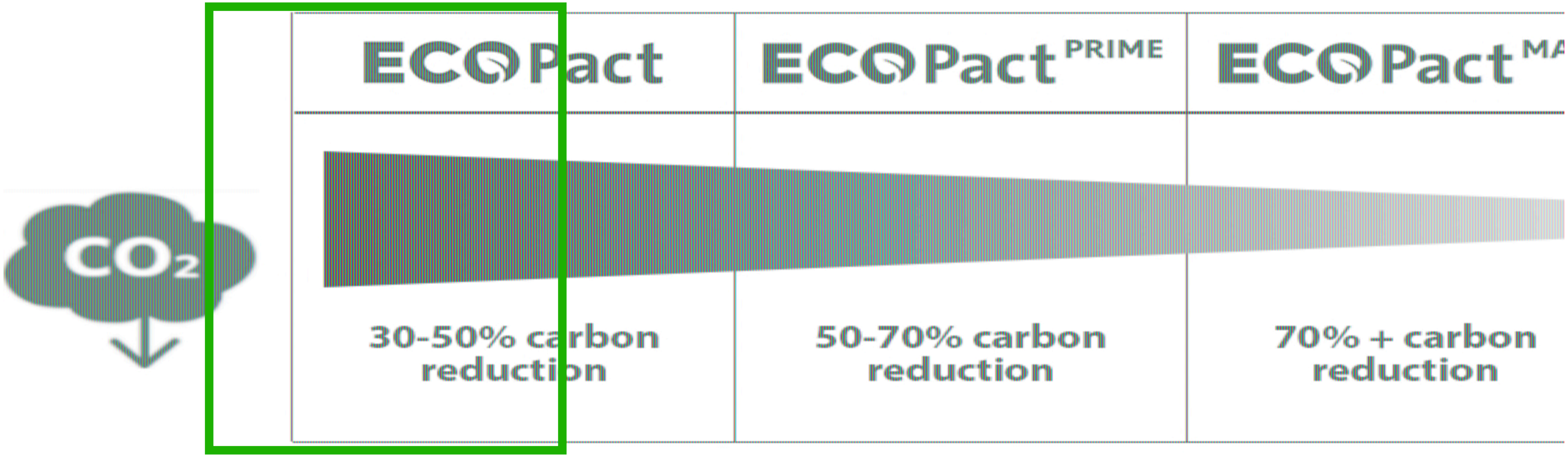
Extravagant numbers compared with:

0.2 t CO_2/ 1t GP- cement,

or for Portland cement: 0.9 t CO_2 / 1tonne OPC.

2020 GEOPOLYMERCAMP

2020 HOLC (LAFARGE)



30-50 % reduction based on addition of GGBS granulated ground blast furnace slag, from steel industry, and Fly ash.

2 major flaws:

a) There is not enough GGBS produced by the steel industry.

b) But above all, this production of the by-product GGBS will be stopped because of the transformation of the manufacturing processes.

14 July 2021

[Liberty Galați exports 50,000t of granulated blast furnace slag to French clinkerless cement producer](#):

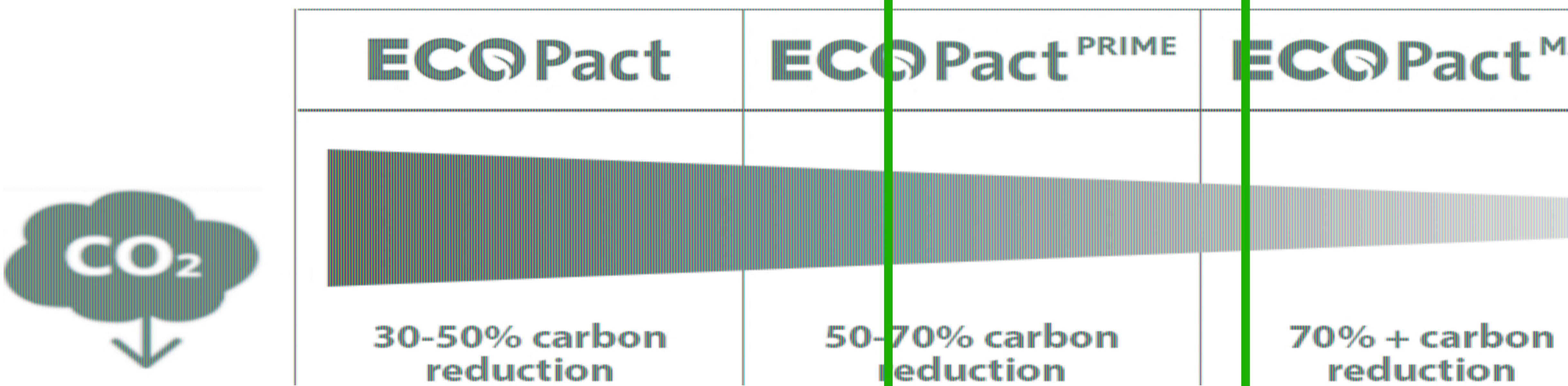
Romania: (…) Liberty Galați's operations generate 500,000t/yr of GGBS, has cement industry customers in Europe and Africa.

General Director Aida Nechifor said "***Our ambition to become carbon neutral by 2030 involves a new metallurgical route*** – ***using direct iron reduction and smelting in electric arc furnaces*** – *(…..)*

However, we are very happy to be able to ensure that the by-products of our current production process,GGBS, can be used to help reduce the carbon footprint of other products." i.e.: ***2030 no more GGBS*** for Portland Cement.

2020

HOLC (LAFARGE)



ECOPact Max

Above 70% Carbon Reduction

Our lowest carbon range of concrete using ce
alternative technology such as Geopolymers a
activators, offering a minimum of 70% CO_2 re
compared to a standard concrete (CEMI) mix.

2020

Low carbon dioxide concrete from Cemex S.A.B. de C.V. will soon be available in the producer's major markets worldwide after a successful launch in Europe.

A series ranging from low carbon to net-zero CO2 mixes, *Vertua is based on a geopolymer binder solution*. Compared to conventional materials, it has a reduced carbon footprint of up to 70 percent without sacrificing performance in finished concrete.

This should facilitate and accelerate the implementation of the much needed standards.

INSTITUT GÉOPOLYMÈRE

Visit by Prof. Joseph DAVIDOVITS
of the first airport made out of
geopolymer cement with company
Wagners' Earth Friendly Concrete® (EFC)

WAGNERS

1800-1211-595
info@geocement.in

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Kilpauk, Chennai- 600 010.
Tamilnadu, INDIA.

Support Team
24 X 7

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KIRAN GLOBAL
CHEMS LIMITED

India

Green Geocement > About Kiran Global Geocement

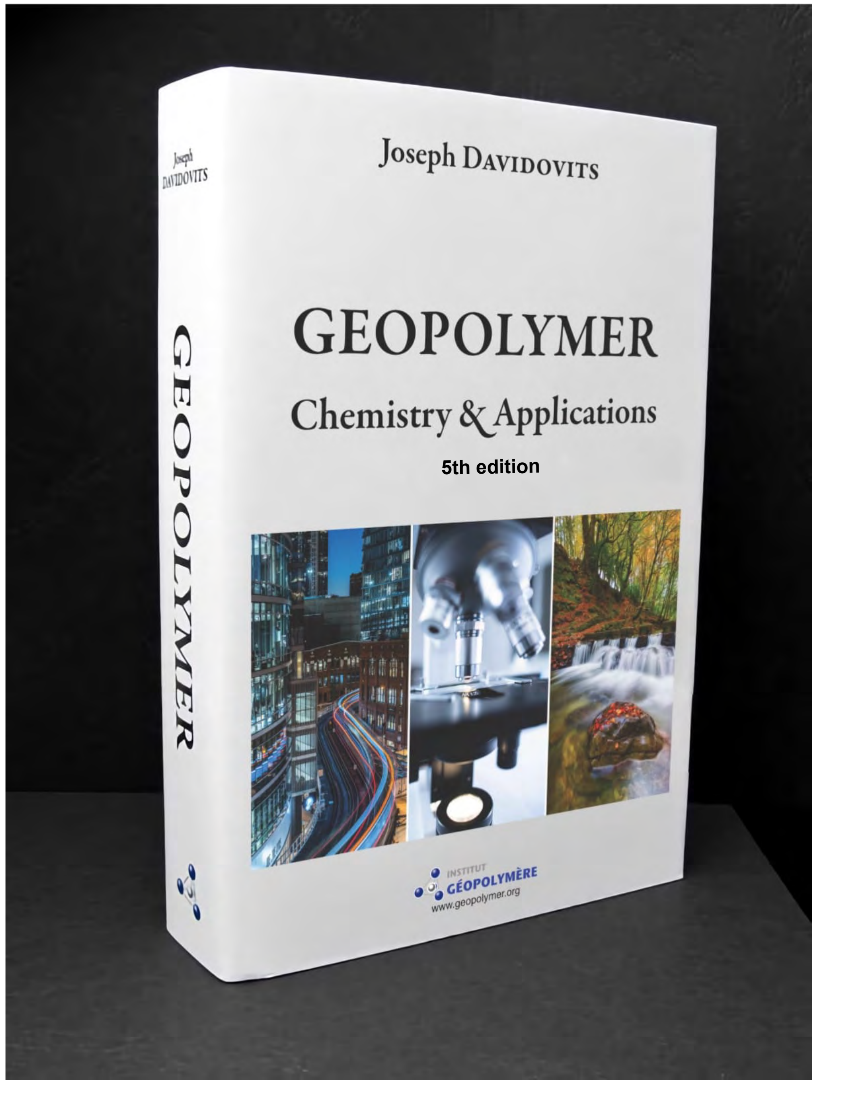
2nd world-largest alkali-silicates manufacturer

MS Jain Group started its journey in the chemical manufacturers industry as a small scale manufacturing unit with the vision to leave its mark as a visionary innovator. From 1979 to this date, the company has grown under the able leadership of founder and Chariman **Mr. MS Jain** as a leading conglomerate with international presence. We have manufacturing units in more than five countries and our chemicals import- export business spans the five continents.

Passive cooling in buildings

A) Chapter 24 (5th ed.) Geopolymer Foam

B) Chapter 14 (5th ed.) Phosphate based geopolymer.



24.3 Passive cooling of buildings i
arid climate

Yet, the poly(sialate) framework provides an addit
property, the ability to absorb and desorb quickly
olitic water), that can be very useful for another
insulation: passive cooling of buildings in hot arid c

Passive cooling in buildings

In this present case, geopolymeric foam absorbs 10–15 % by weight of vapor humidity in a few hours at 20°C when put in an atmosphere from 56 % humidity to 90 % humidity.

3 boxes are constructed with insulating material of the same thermal conductivity of 0.058 kcal/m.h.°C:

– one with polystyrene foam, 4 cm thick;

– one with glass wool, 4.5 cm thick;

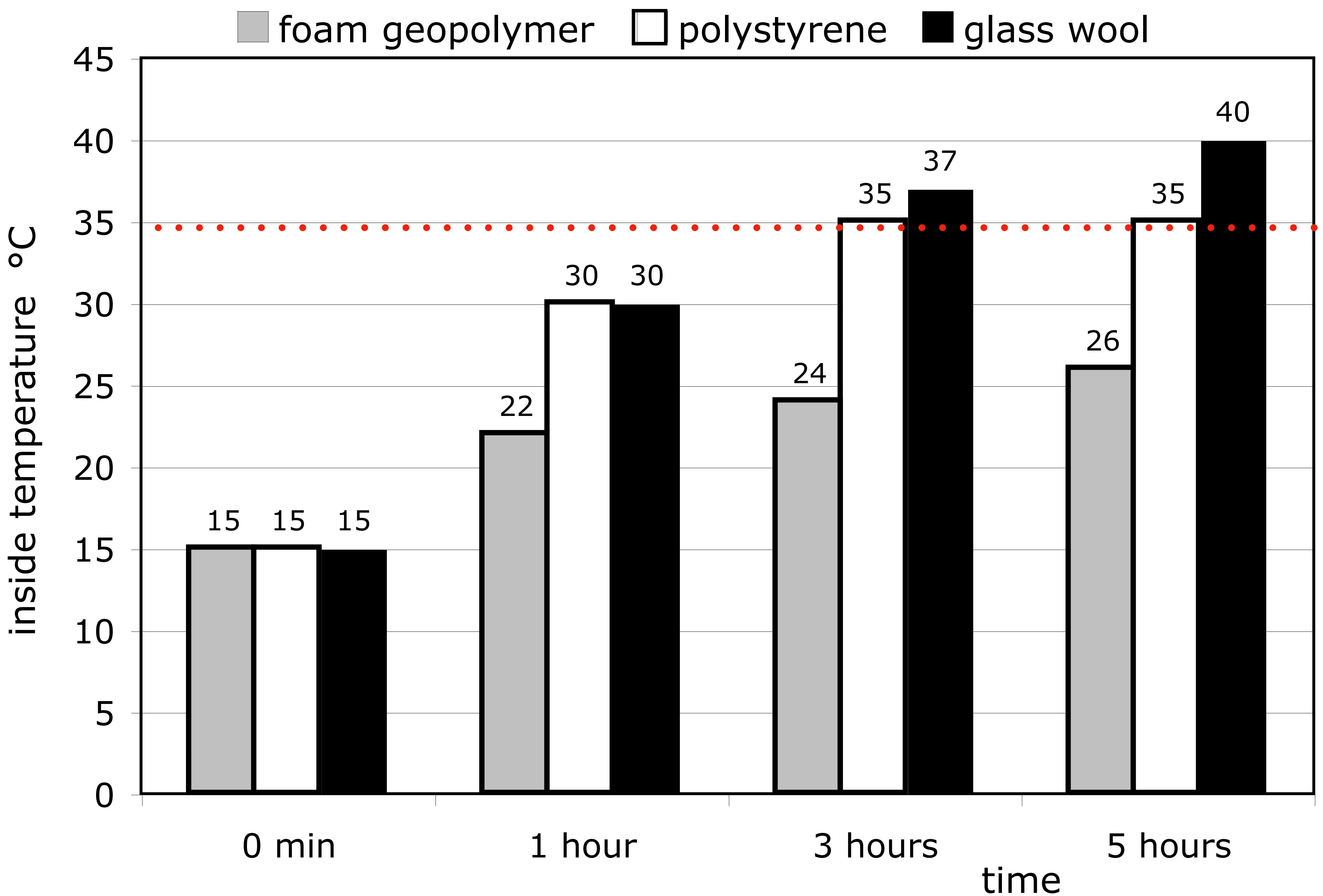
– one with geopolymer foam, 6.5 cm thick;

The thicknesses correspond to the same insulating value. Starting temperature of all materials is 15°C. The 3 boxes are put together in a room at 35°C, humidity 52 %.

Passive cooling in buildings

The temperature of the interior volume in each box is measured at different times, and the increase of the inside temperature plotted.

Outside T°
35°C
H: 52%
Temperature inside the 3 boxes



Passive cooling in buildings

2019

ACS APPLIED MATE & INTE

Robust Inorganic Daytime Radiative Cooling Coati Phosphate Geopolymer

Guoliang Chen, Yaming Wang,* Jun Qiu,* Jianyun Cao,* Yongchun Zou, S and Yu Zhou

ABSTRACT: Daytime radiative cooling can spontaneously cool an object by reflecting sunlight and radiating heat in the form of infrared rays. Current daytime radiative cooling designs, including photonic structures and organic polymer-dielectric systems, are prone to age and fail under harsh conditions including high temperature, mechanical wear, and/or space irradiation.

An all-inorganic phosphoric acid-based geopolymer (PGEO) paint was developed and showed robust radiative cooling performance. This versatile suspension paint can be applied directly to diverse surfaces through scalable techniques such as spray coating and brushing.

ACS APPLIED MATE
& INTE

Robust Inorganic Daytime Radiative Cooling Coati
Phosphate Geopolymer

Guoliang Chen, Yaming Wang,* Jun Qiu,* Jianyun Cao,* Yongchun Zou, S
and Yu Zhou

This inorganic coating possesses a high average hemispherical infrared emissivity >0.95 and reflects nearly 90% of solar irradiance.

(…) This excellent spectral selectivity of the PGEO coating is based on its unique inorganic geopolymer network (−Si−O−Al−O−P−O−), which settled the vibration intensity in a suitable range ($0.2 < k < 1$) and enabled multimode vibration. This inorganic coating exhibits good performance in terms of heat endurance, mechanical strength, and resistance to intense proton radiation, showing promising applications in spacecraft, buildings, and communication base stations.

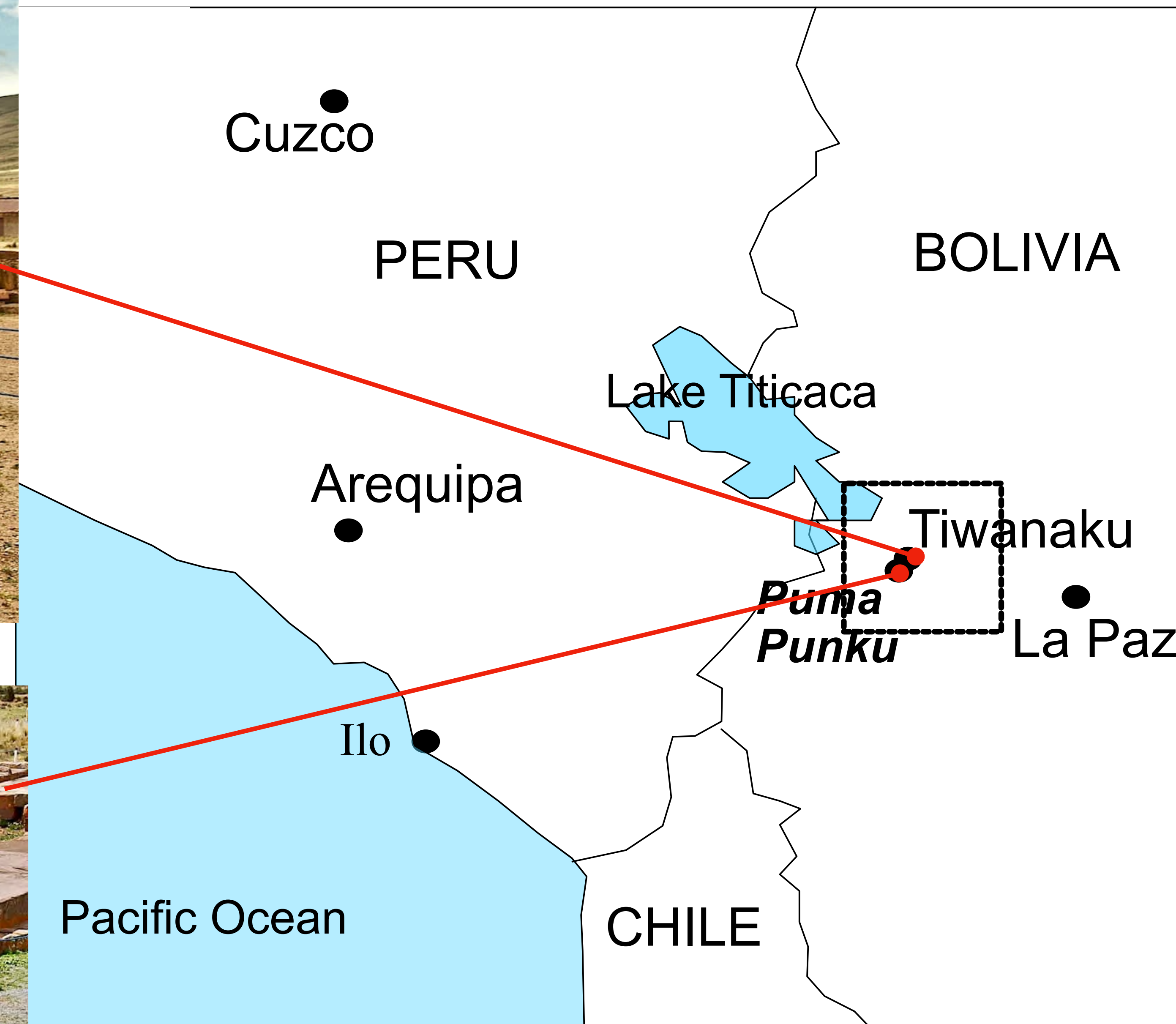
This excellent spectral selectivity of the PGEO coating leads to a subambient temperature drop at the coating surface up to 8.3 °C under direct sunlight. (…)

State of the Geopolymer R&D 2021

1) Geopolymer science

2) Global warming

3) Geopolymer and archaeology:
South America and Easter Island



Built ca. AD 600 1400 years ago

Destroyed ca. AD 900

500 years before Inca Empire

Two different methods:

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

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

(organic acids-phosphate)-geopolymer cement

Contents lists available at ScienceDirect

Materials Letters

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

ELSEVIER

2019

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

Check for updates

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.

Contents lists available at ScienceDirect

Ceramics International

Ceramics International, 45 (2019) 7385-7389

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

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CERAMICS INTERNATIONAL

2019

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

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.

online 04 January 2019

GEOPOLYMER
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Geopolymer and A

A Journal on Geopolymer Science

available online at: geopolymer.org/library/gpsa

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Geopolymer and A

A Journal on Geopolymer Science

G. Demortier / Geopolymer and Archaeology (2020) 1-9

available online at: geopolymer.org/library/gpsa

Distribution of sodium and chlorine in samples of E

Guy Demortier*

Emeritus professor of physics, University of Namur (Belgium)

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Geopolymer and A

A Journal on Geopolymer Science

F. Davidovits / Geopolymer and Archaeologie (2020) 10 - 35

available online at: geopolymer.org/library/gpsa

Carbunculus, extrait de la thèse « *Géologie et construction dans le De architectura de Vitruve* » (2007)

Frédéric Davidovits Ph. D. 11 août 2020

DOI registered at Research Gate as Preprint: 10.13140/RG.2.2.26618.72644

GEOPOLYMER INSTITUTE

Geopolymer and A

A Journal on Geopolymer Science

J. Davidovits and F. Davidovits / Geopolymer and Archaeology (2020) 36-43

Ancient geopolymers in South-American Monum use of natural andesite volcanic sand (r

Joseph Davidovits and Frédéric

ABSTRACT

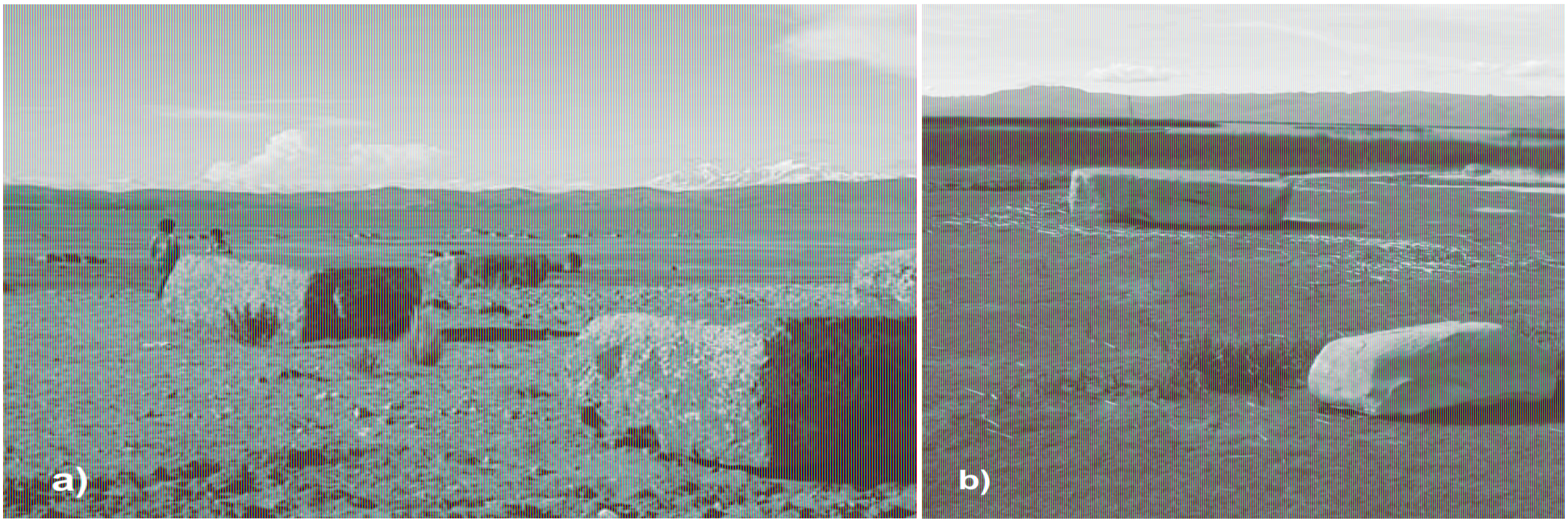
…………..

To make geopolymer andesite stone, around AD 600 to AD 700, the builders had transported an andesite stony material having the ***texture of natural volcanic sand*** from the Cerro Khapia volcano site, and added an organo-mineral geopolymer binder manufactured with local biomass ingredients.

This in contradiction to what traditional archaeology is claiming, namely that...

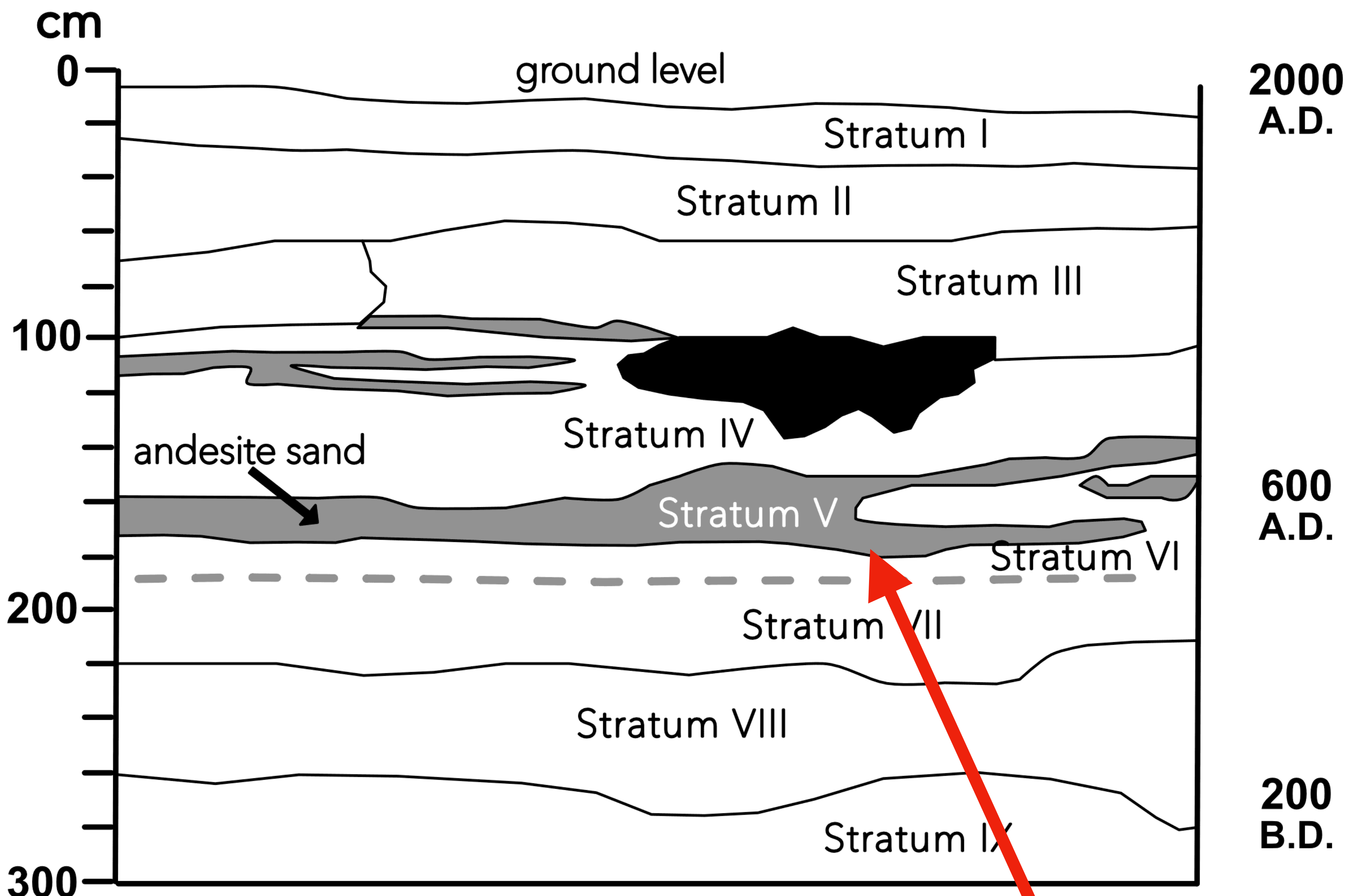
they used the many quadrangular volcanic blocks, the famous "*piedras cansadas*", the tired stones, which are still lying on both sides of the lake Titicaca,

a) Kanamarca / Peru — b) Iwawe / Bolivia



Piedras cansadas, the work done by the Incas, 800 years later, AD 1400.

In opposite, the present paper describes how the builders of Pumapunku / Tiwanaku exploited a natural volcanic andesite sand from the volcano Cerro Khapia, transported and stored it at the shore village of Iwawe,



Excavations at Iwawe / Bolivia Isbell & Burkholder, (2002)

Andesite volcanic sand in Stratum V, 1.6 m below ground level, dated to AD 600, time of the construction in Tiwanaku/Pumapunku.

For the making of their andesite geopolymer monuments, they did not need to crush andesite rock.

GEOPOLYMER INSTITUTE

Geopolymer and A

A Journal on Geopolymer Science

T.A. Gara, J. Davidovits, F. Davidovits, Geopolymer and Archaeology (2020) 1, 44-53

available online at: geopolymer.org/library/gpsa

Considering Certain Lithic Artifacts of Tiahuanaco Pumapunku (Bolivia) as Geopolymer Con

Thomas A. Gara[a], Joseph Davidovits[b], Frédéric Davidovit

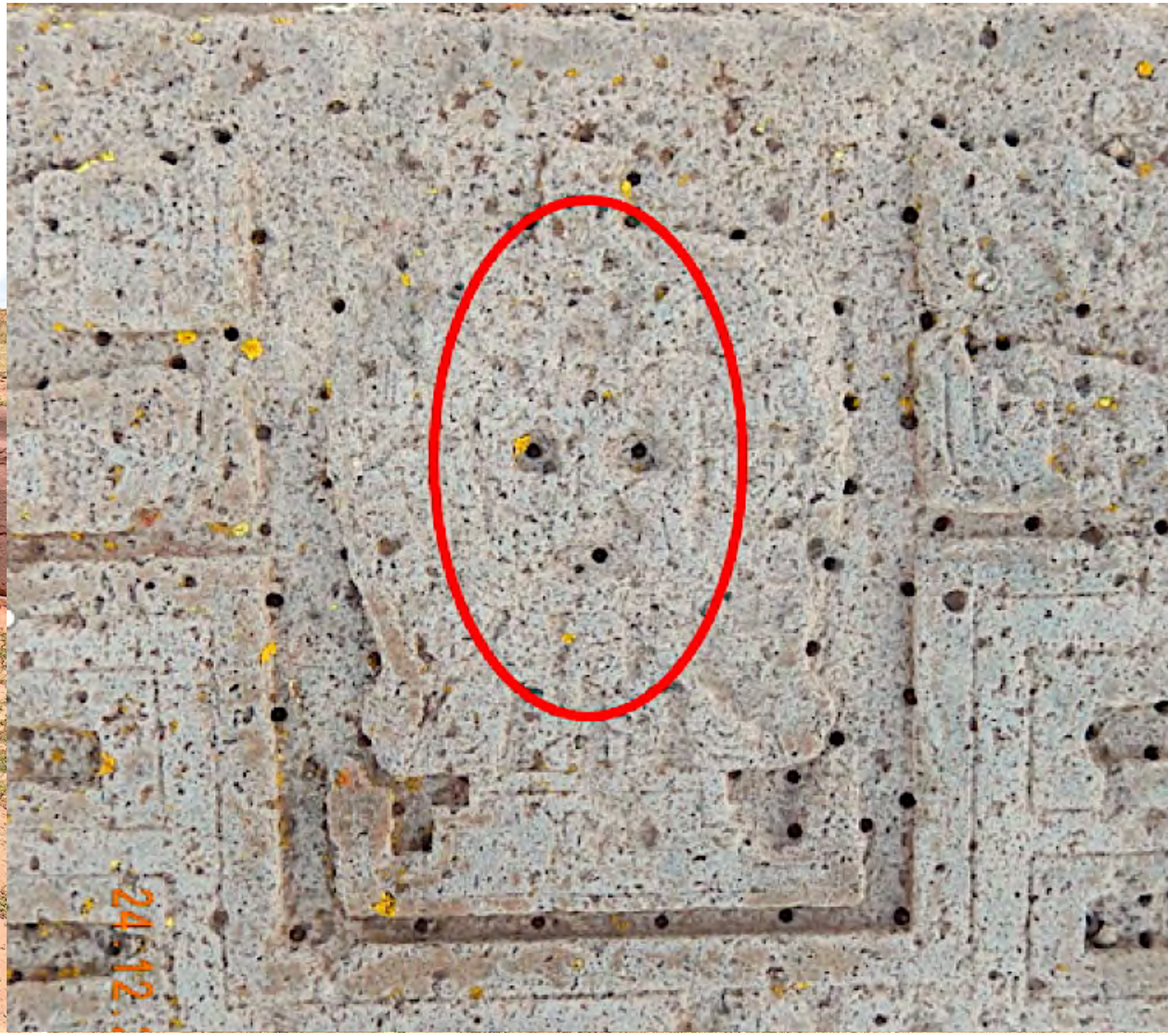
[a]Schongauer Institute, 81377, Munich, Germany [b]Geopolymer Institute, 0210

Abstract

(…) The two types of lithics under consideration are large platforms and 'sculptures' exhibiting characteristics that would have been extremely difficult, if not impossible, to achieve with the tools thought to be available to the Tiahuanacans' of 1400 years ago.

For examples, big lithics exhibit perforations of unique characteristics. These holes, believed to be boreholes, are found in andesite artifacts, impossible to drill. In number, they approach 900 perforations.

Pumapunku monolithic andesite gate



Numerous holes/perforations of 3 or 4 mm diameter.

They could have been created with wooden dowels forced into the ***plastic geopolymer***, before complete hardening, or reed or copper tubes forced into the material in the same way cookie cutters remove the cookie from the dough.

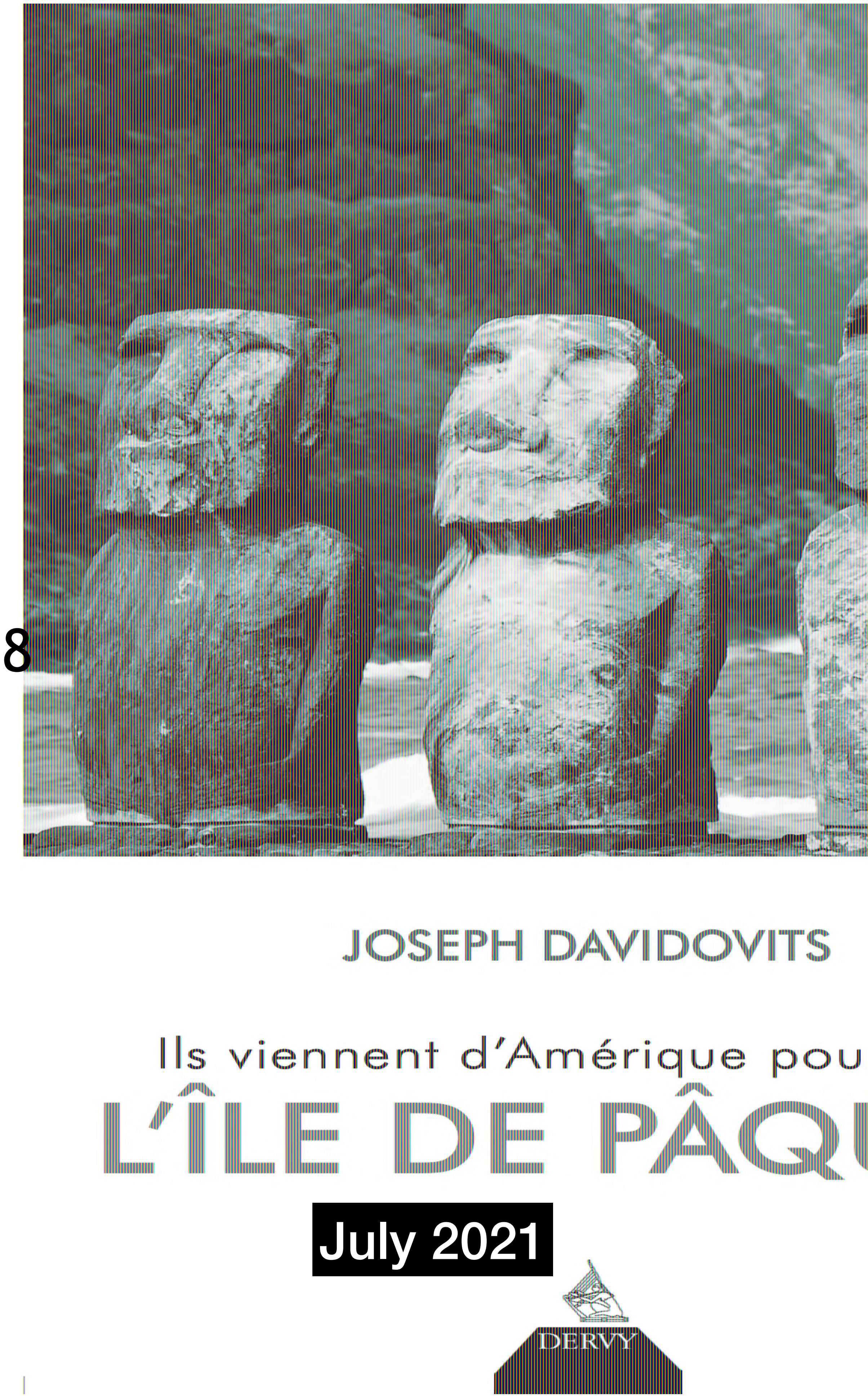
The paper also discusses other geopolymer lithics .

They came from America to build Easter Island

2 Parts:

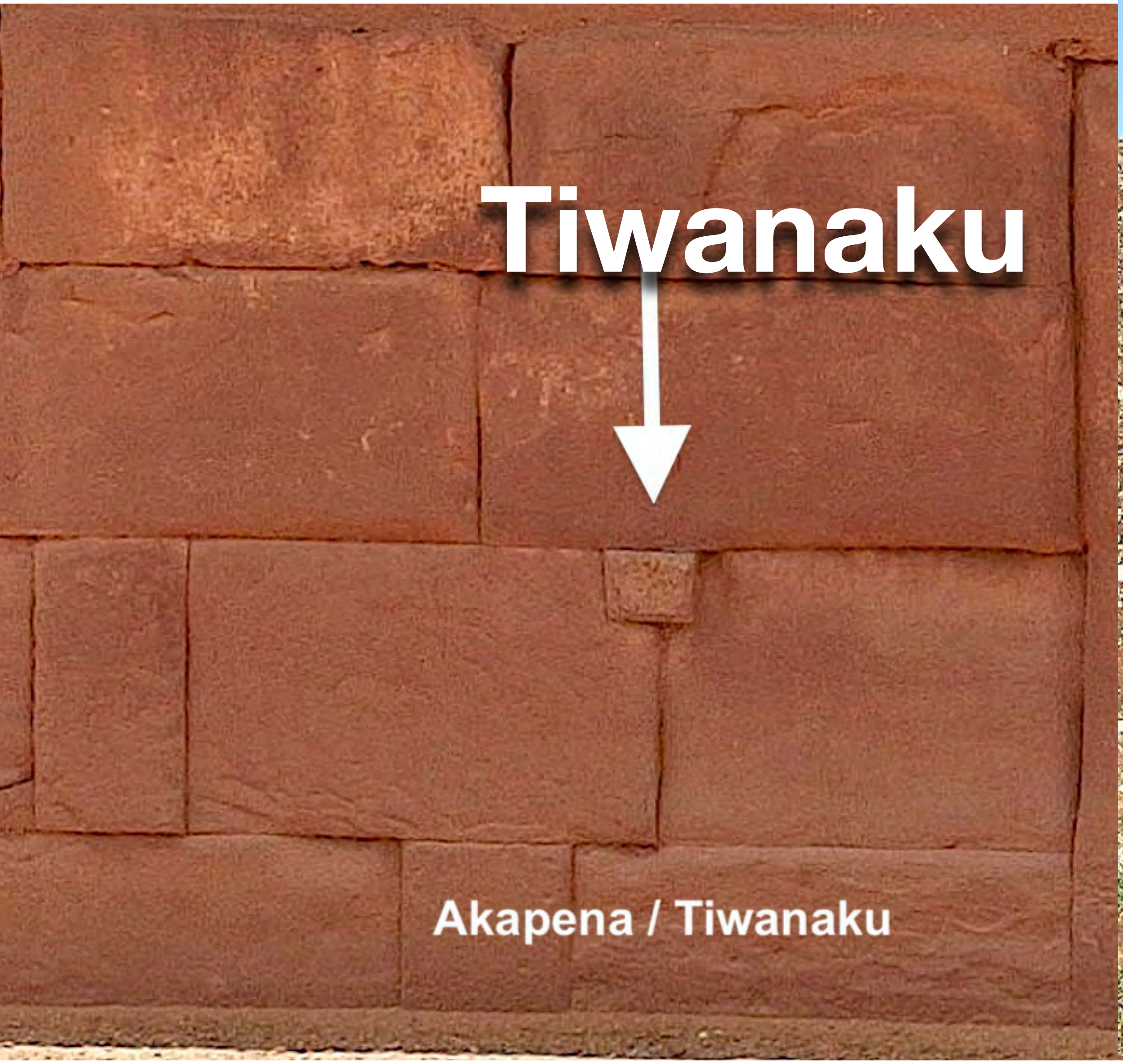
1- explaining the discovery in 2017-2018 of the use of the Geopolymer stone technologies implemented at Pumapunku/Tiwanaku (600-800 AD).

2- the transfer of geopolymer technology to the monuments and statues of Easter Island, also made of artificial geopolymer stone.



Easter Island: *Vinapu* wall

AD 900 ?

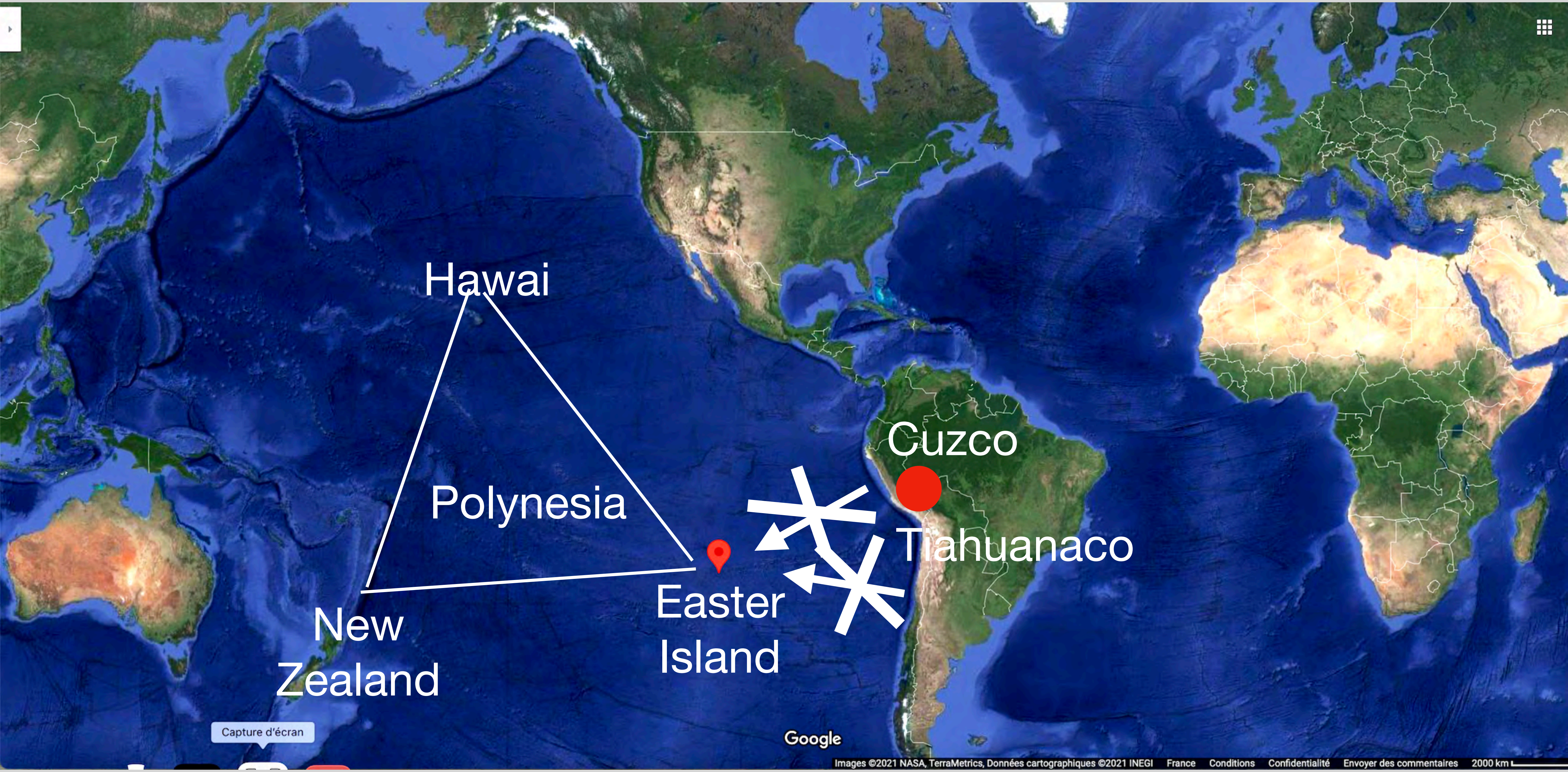


Tiwanaku AD 600-650

Easter Island AD 850-950

Does same architecture means same geopolymer technology ?

What is the problem ?



Do we have scientific analysis?

Standing statues, *Moai*, on the Ahu Tongariki.

Do we have scientific analysis? Yes

Distribution limitée
RM/PP/CONSULTANT

Ile de Pâques

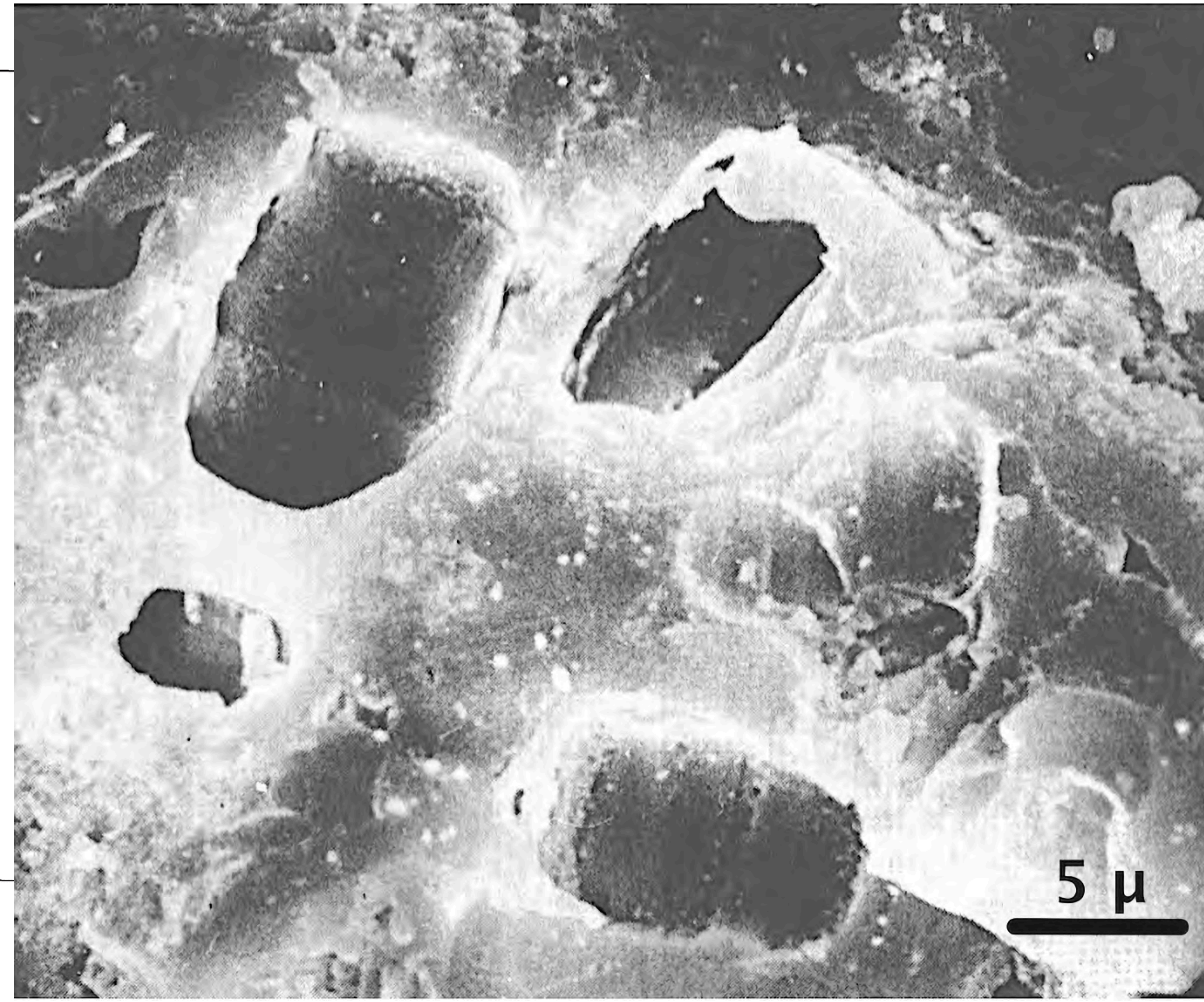
Les statues de Rapa Nui
Conservation et restauration

février-mars 1972

par G. Hyvert (Mlle)

Nº de série : 2868/RMO.RD/CLP
Paris, mars 1973

Unesco

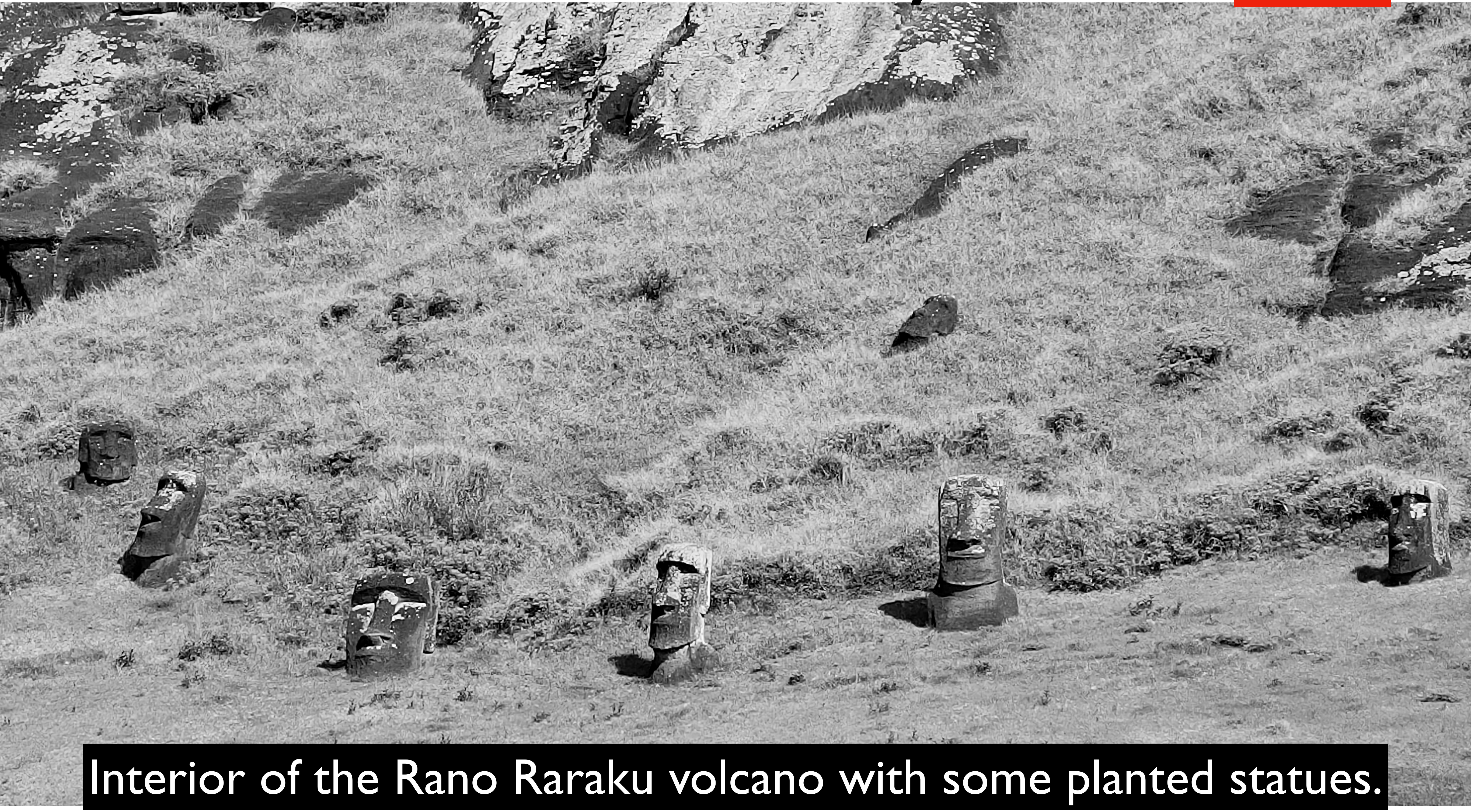


barrel-shaped fossilized micro-organisms (bact

Chemamülles

Rano Raraku volcano

Do we have scientific analysis? Yes: 2019

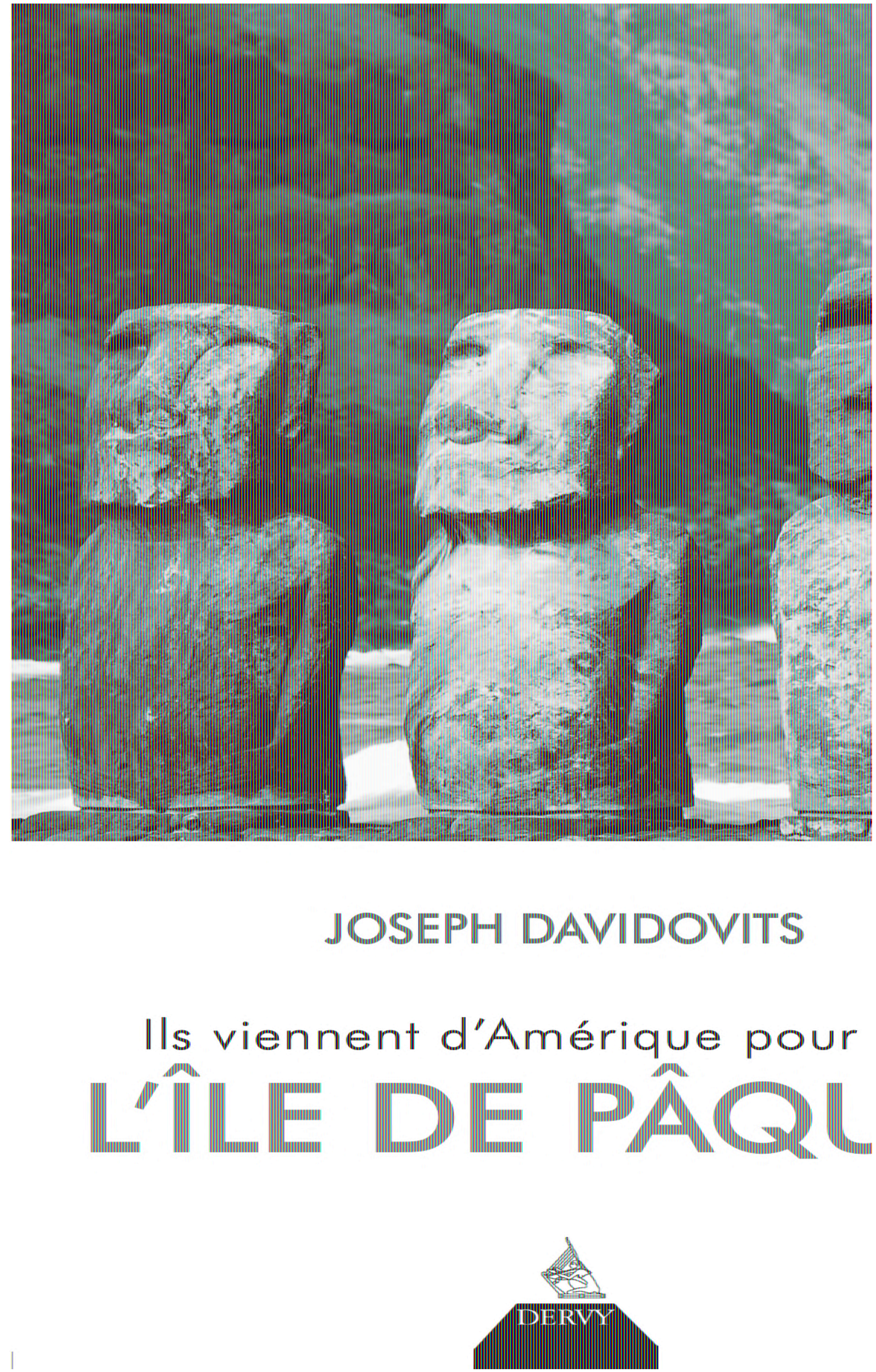


Abnormally heavy concentration of chemicals resulting from geopolymer manufacturing unit ?

They came from America to build Easter Island

July 2021

First published in French. Spanish and English translations are available. Search for qualified publishers.



State of the Geopolymer R&D 2021

GeopolymerCamp 2020

Joseph Davidovits

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UNIVERSITÉ de Picardie Jules Verne

CAMPUS universitaire de Saint-Quentin

PÔLE TECHNOLOGIQUE

2021 GEOPOLYMERCAMP

13th GP-Camp

LTI PÔLE TECHNOLOGIQUE SAINT-QUENTIN

UNIVERSITÉ de Picardie Jules Verne

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Saint-Quentin (France)

Aug. 30-31, Sep.1, 2021