The manufacture of metakaolins

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Imerys: 2016 Key figures

€4.2 bn
Revenue

€582 m
Current operating income

14.0%
Operating margin

16 000
Employees

260
Operating sites

50
Countries

8
R&D centers

#1 or #2
On most of our markets

€6.0 bn
Market capitalization
54% of capital held by GBL

UN GLOBAL COMPACT

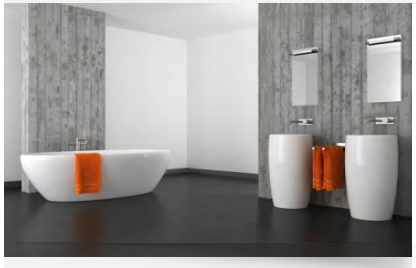
FTSE4Good

EURONEXT vigeo Europe 120

MSCI 2015 Constituent MSCI Global Sustainability Indexes

Imerys offers high value-added functional solutions

Whiteness and **toughness** of sanitaryware, floor and wall tiles



World leader in ceramic bodies for sanitaryware

Lifespan and **fast charging** of electric vehicle lithium-ion batteries

World leader in conducting additives (graphite, carbon black)

Gloss and **opacity** for paint

World leader in wollastonite and talc for paint

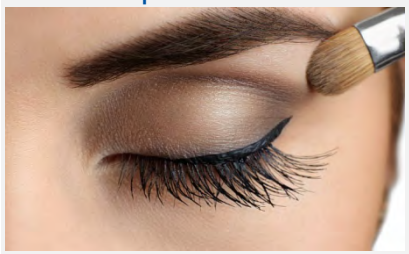
Thermal and **mechanical resistance** of industrial abrasives

World leader in fused minerals for abrasives

Resistance and **lightness** of automotive plastic parts

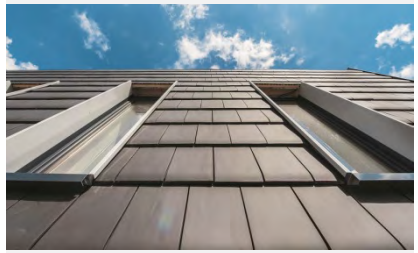
World leader in talc-based performance additives for plastics

Softness of natural mineral powders



World leader in talc for health and beauty

Watertightness and **insulation** of roofs



French leader in clay roof tiles

Filtration of liquids (food or blood plasma)

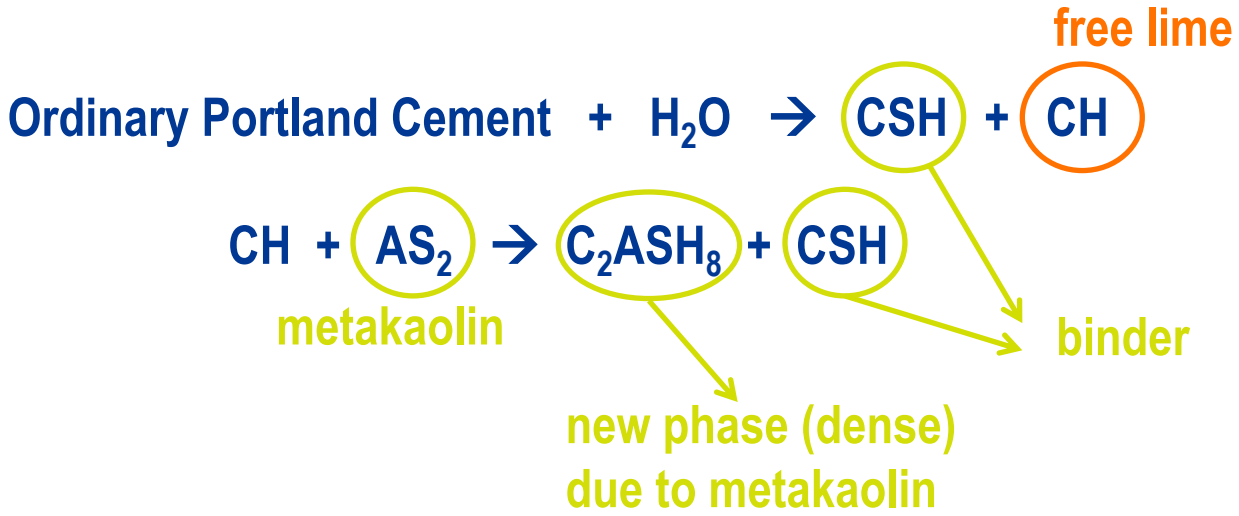
World leader in perlite and diatomite for filtration

Imerys presence is diversified in many markets and regions

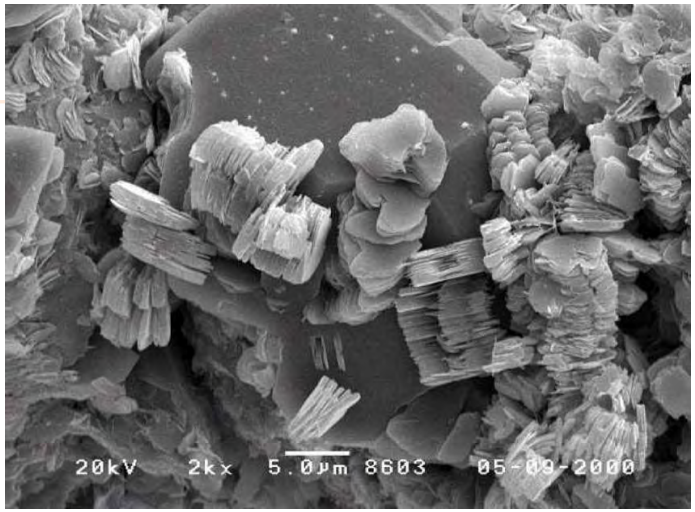
The world leader in mineral-based specialties for consumer goods, industrial equipment and construction, with presence in more 50 countries

What is a Metakaolin?

- Metakaolin is an **amorphous state** of kaolinite obtained by firing the mineral at a temperature between 700 and 950°C.
- It is a **pozzolanic** material, i.e. it reacts with lime in the presence of water.
  - In cementious materials, metakaolin reacts with the lime released by the cement during its hydratation; it also reacts with the lime added in some mortars.
  - Pozzolanic reaction:



What is Metakaolin?



Thermal transformation of Kaolin / Kaolinite

Kaolinite : $2SiO_2\ Al_2O_3,\ 2H_2O$

Water — **Deshydroxylation** — 500-550°C

Métakaolinite $2SiO_2\ Al_2O_3$ — 750-950°C

960-980°C

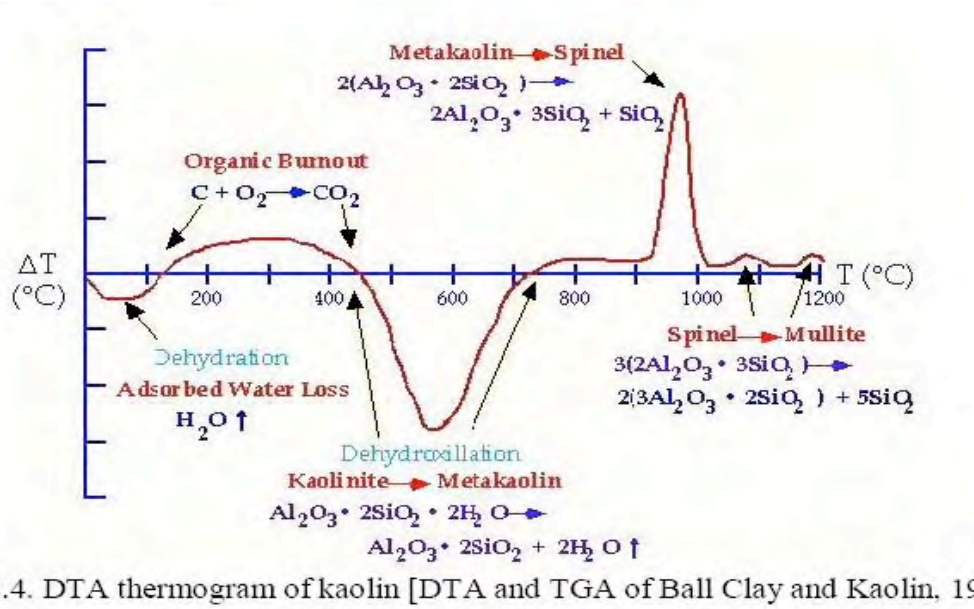
Si-Al Spinelle $Si_3Al_4O_{12}$

1100-1150°C

Mullite $3Al_2O_3\ 2SiO_2$

Chamotte

Over-heating = densification and loss of pozzolanicity



2.4. DTA thermogram of kaolin [DTA and TGA of Ball Clay and Kaolin, 19

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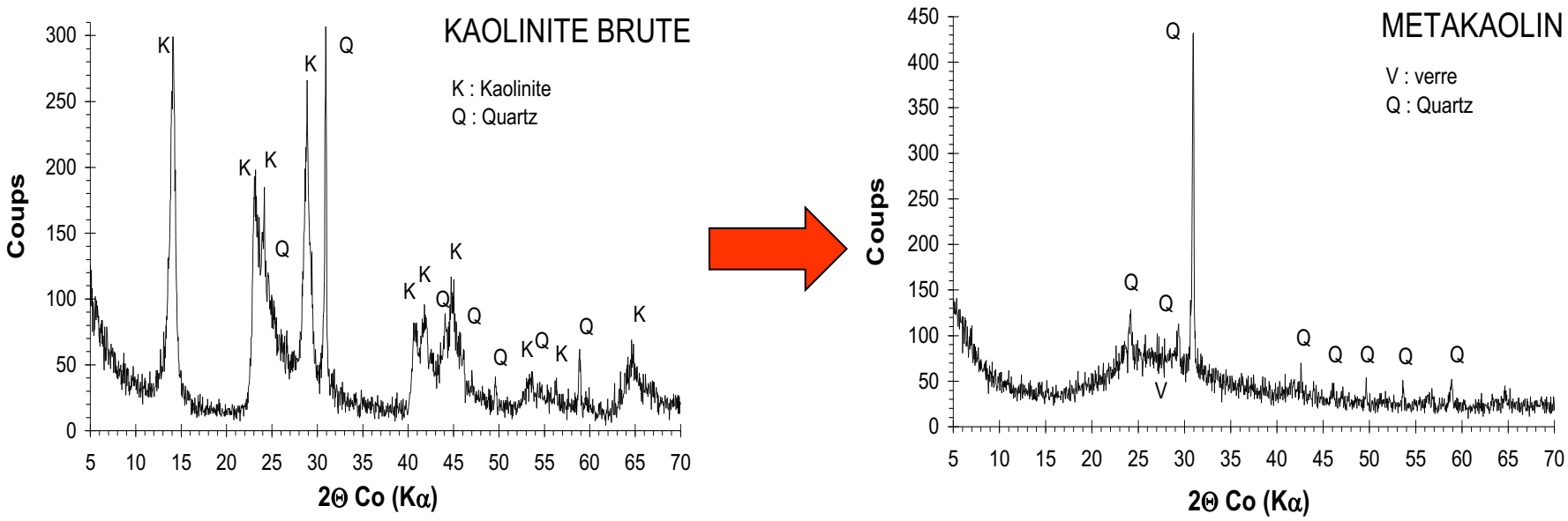
What is Metakaolin?

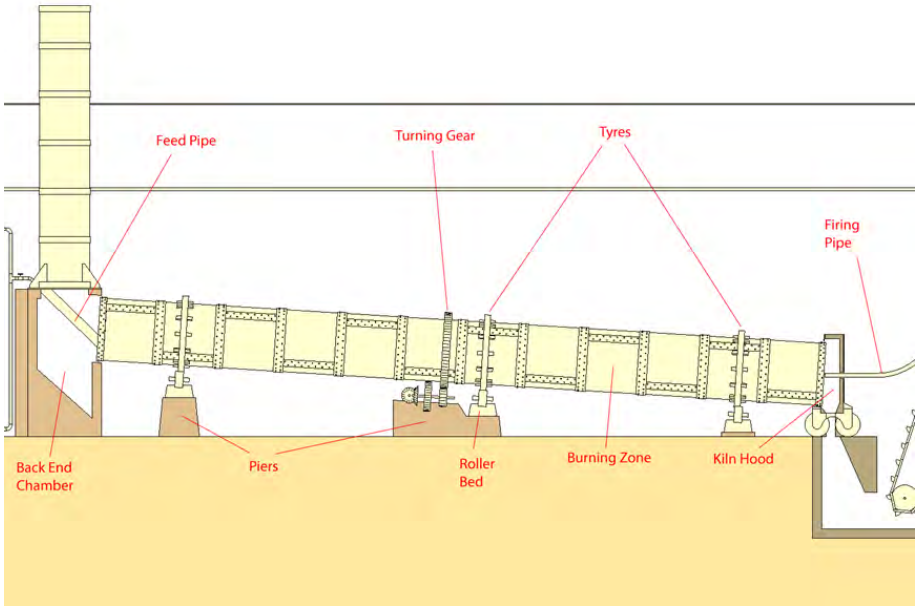
XRD shows the transformation of kaolinite to amorphous.
Amorphous state is the one of interest for Geopolymer.



The manufacture of metakaolin: processes of calcination

- There are several industrial processes to calcine a kaolin clay, some known since Antiquity.
- Two main processes used within Imerys:
  - Continuous furnaces: wherein loads are moved through temperature zones continuously of intermittently
    - Herreshoff multilevel kiln: UK, USA
    - Rotary kiln: France (Clérac), Ukraine (Vatutine), USA (Andersonville)
  - Flash kilns:
    - Torbed calciner: UK
    - Flash kiln FCB type: France (Clérac)

Processes of calcination: rotary kiln



www.cementkilns.co.uk

Rotary kiln at Imerys Refractory Minerals Clérac (France)

L= 34 m; ø 2,5 m

Throughput: 10 tonnes per hour

Fuel oil + Biogas + Sawdust

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Processes of calcination: rotary kiln

Advantages

- The technology is reliable and robust (similar to a cement plant).
- Efficient energy consumption: 800-1200 kWh/t
- Good throughput rate: 10-12 tonnes/h

Drawbacks

- Dehydroxylation control after heating: need to have a good knowledge of the process.
- The feed material is shaped as pellets → temperature gradient in the pellet.
- Product has to be milled after calcination.
- The kiln has to be run continuously so need of a certain volume or combination with other materials.

Products available:

- ARGICAL M-1000 (France)
- MK-40 (Ukraine)

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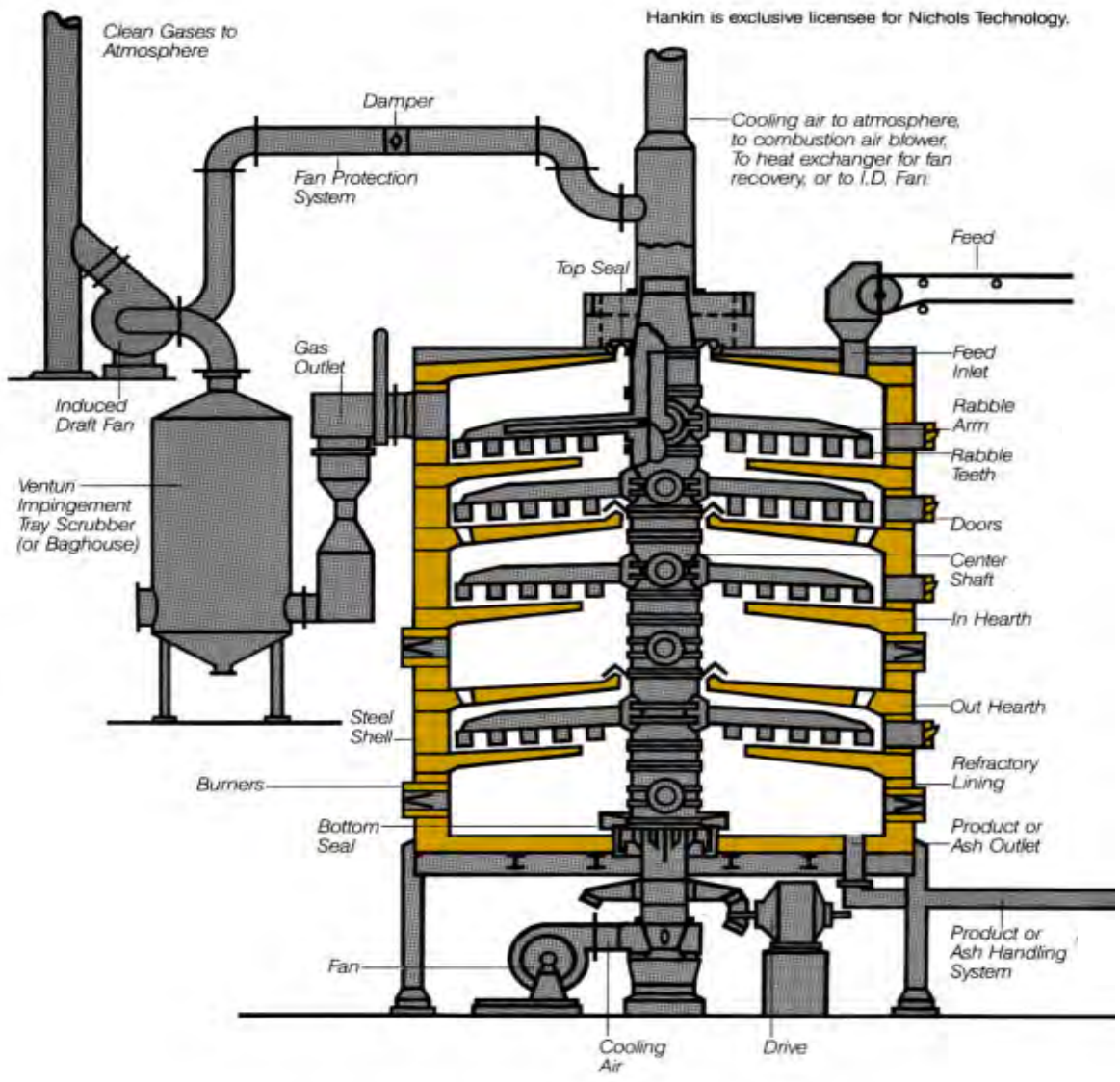
Processes of calcination: Herreshoff kiln



Processes of calcination: Herreshoff kiln

Advantages

- Technology is reliable and robust (similar as rotary kiln).
- Efficient energy consumption: 600-1200 kWh/t
- Good control of temperature of calcination

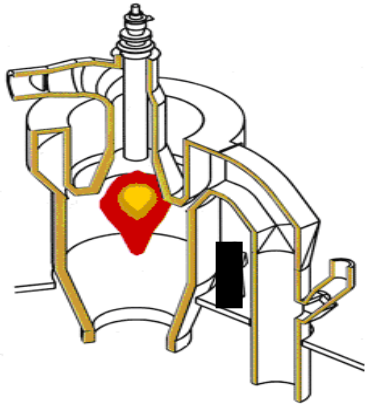
Drawbacks

- Dehydroxylation control after heating: means to have a good knowledge of the process
- Thermal inertia of the kiln
- Huge investment: 1.5-2 times more than a rotary kiln.

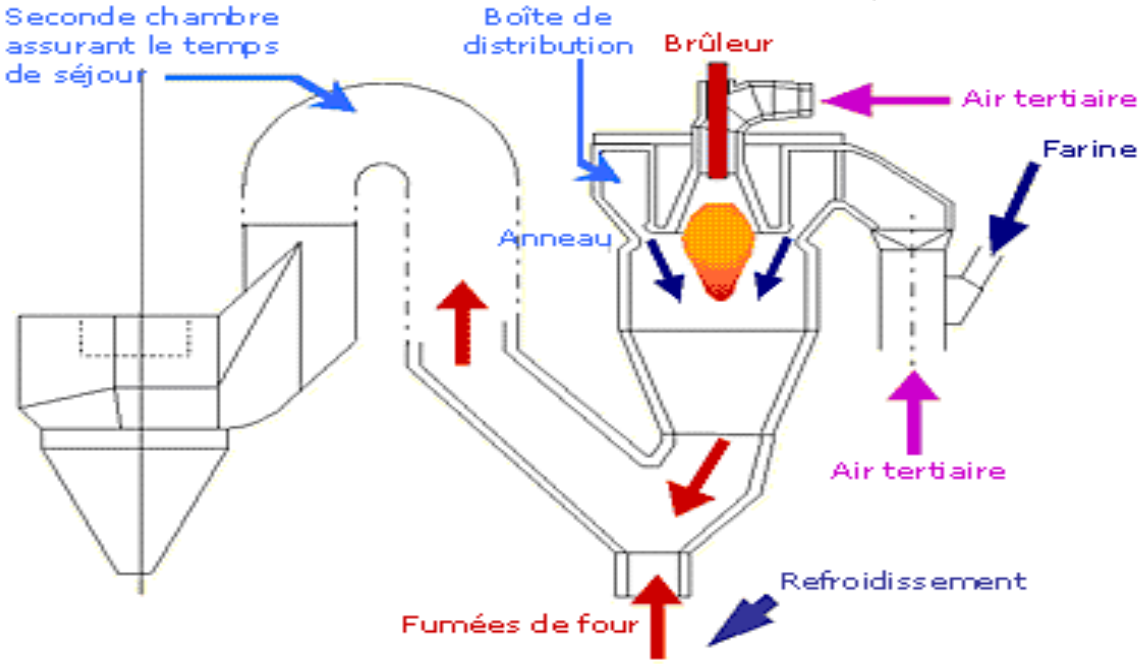
Product available:

❖ METASTAR 501 (USA)

Processes of calcination: Flash kiln



Very short calcination time (second)



Powder inlet

Processes of calcination: Flash kiln

Advantages

- Really flexible: Target temperature quickly reached.
- Precise control of temperture, thus of dehydroxylation.
- Limited energy consumption: 400 to 800 kWh/t
- Capacity of kiln adapted by initial design (1 tonne/h at Clérac).
- Can produce very fine metakaolin (pre milling).

Drawbacks

- Complex operational system.
- Important cost of investment.
- Milled material needed for feed.

Product available:

❖ ARGICAL M-1200S (France)

The manufacture of metakaolin: important parameters

- The quality of the metakaolin is directly linked to the quality of the starting material, i.e. the **deposit** the kaolin clay is coming from.
  - Primary deposit: low levels of TiO_2 and Fe_2O_3, high level of K_2O, low surface area
  - Secondary deposit: more impurities but higher surface area.
- The **amount of kaolinite in the hydrous kaolin** (starting material), reflected by the total chemical analysis, is a main parameter for the reactivity of the final product (metakaolin).
- The process and parameters (time and temperature) of **calcination** are key parameters for reactivity, and the processing of the starting material has also an influence:
  - Pelletisation by pressing before the rotary kiln
  - Drying / milling / air classification before the flash kiln
- **Particle size distribution** (fineness) plays a role, but to a lesser extent: a poorl-reactive metakaolin cannot be improved only by milling.
- A regular **quality control of the final product** is carried out to ensure: reactivity, quality of the calcination, reliability, reproductibility.

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Metakaolins for Geopolymers

Which metakaolin is the best for geopolymers?

- Parameters that are important for the reactivity:
  - Alumina content (Al/Si ratio)
  - Amount of amorphous phase
  - Calcination process
  - Fineness
- Any metakaolin can be used in a geopolymer system. There is no ideal metakaolin for geopolymers; the choice depends on the parameters sought after:
  - Setting time
  - Rheology
  - Mechanical resistance
  - …
- **Tell us what you are looking for!**

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The product range at a glance

Product	Country	Calcination process	Pozzolanic index	Colour	Surface area BET (m^2/g)	d50	Cost basis
METASTAR 501	USA	Herreshoff	1400	+++	14	1 µm	5
ARGICAL M-1200S	France	Flash	1370	++	23	1.5 µm	2
ARGICAL M-1000	France	Rotary	1150	++	19	10 µm	1
MK-40	Ukraine	Rotary	1100	+	15	20 µm	1

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Thank you for your attention

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