

# An Introduction to Metakaolins

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# An Introduction to Metakaolins



## What is Metakaolin?

The Manufacture of Metakaolin

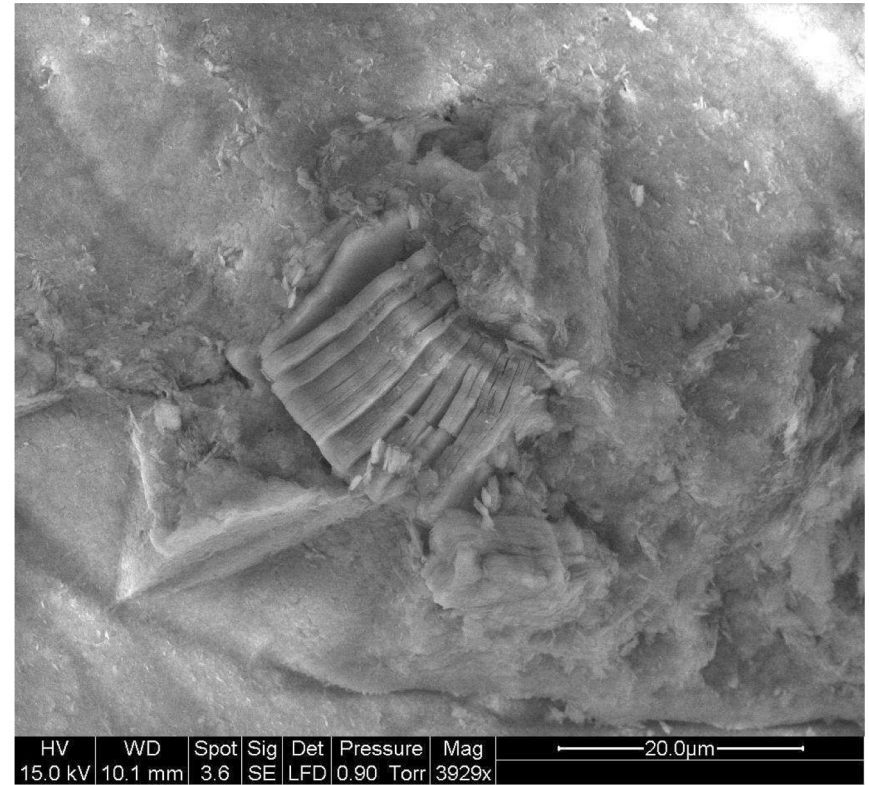
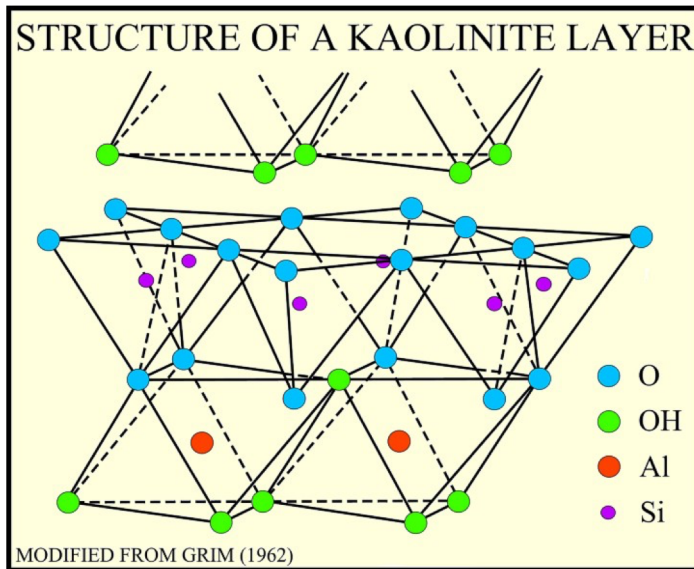
The Properties of Metakaolin



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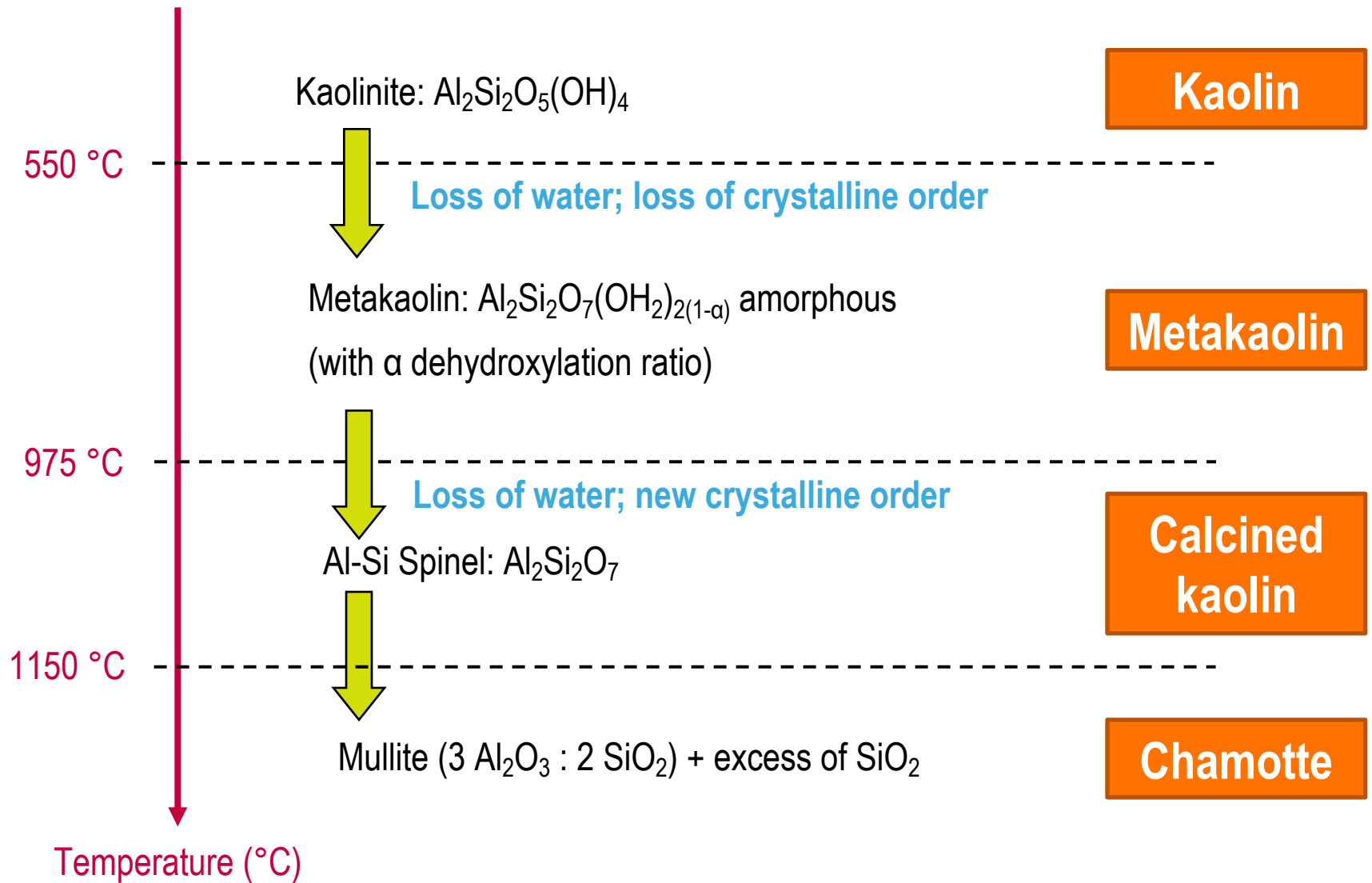
# What is Metakaolin? -- The structure of kaolinite

- **Kaolinite** is a hydrous aluminium silicate:  
 $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$  or  $\text{Al}_2\text{O}_3 \cdot 2(\text{SiO}_2) \cdot 2(\text{H}_2\text{O})$

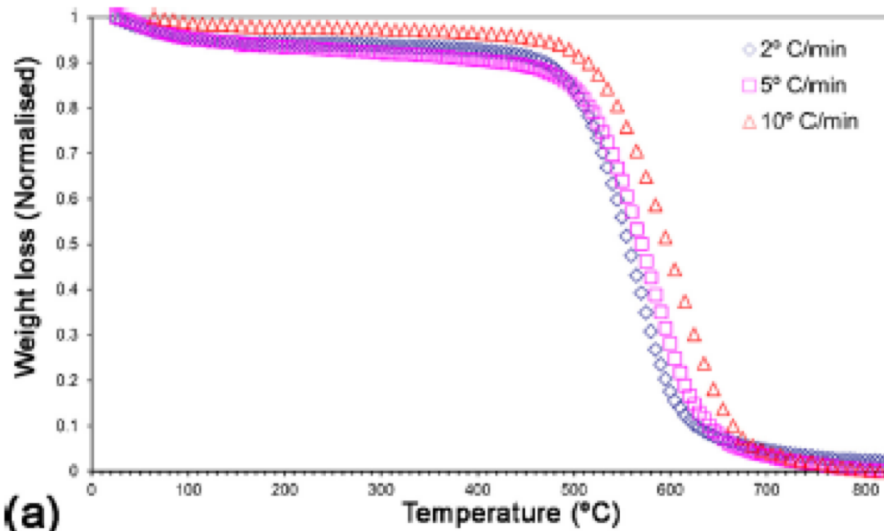


- With heat, water is released from the crystalline structure and the structure is modified.

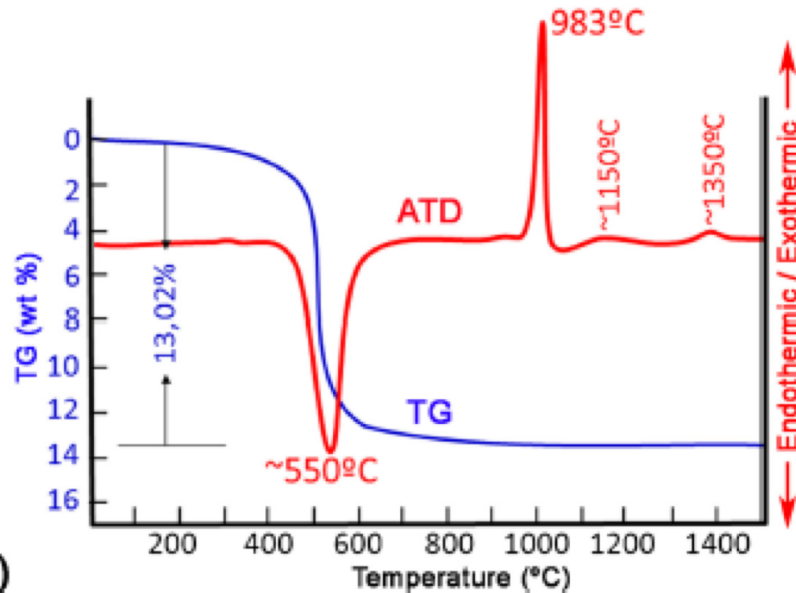
# What is Metakaolin? -- The transformation of kaolinite



# What is Metakaolin? -- The transformation of kaolinite



(a)



(b)

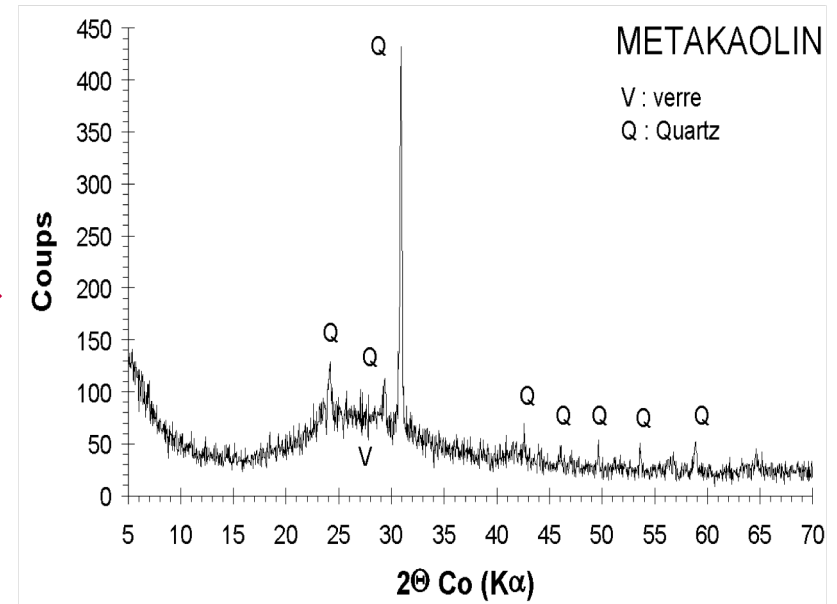
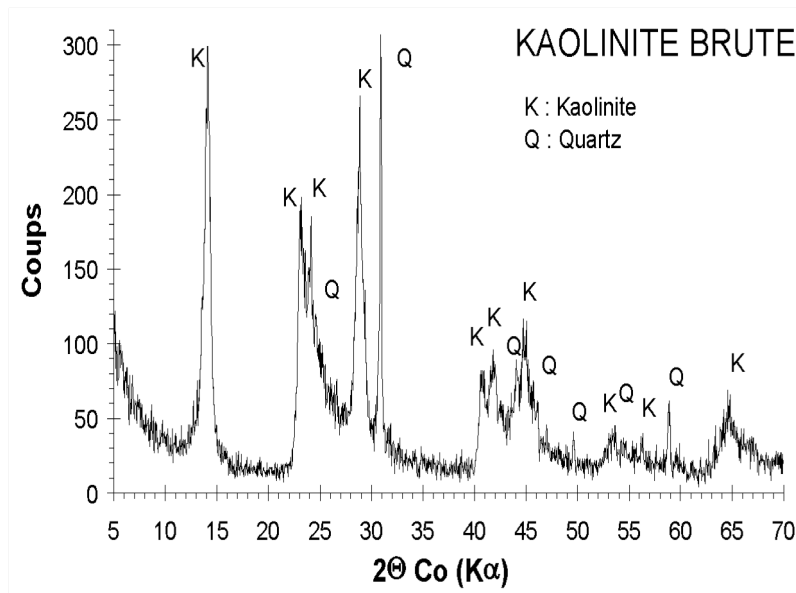
The DTA curve shows a broad endothermic peak at 550°C and a sharp exothermic peak at 983°C.

The main endothermic peak (~550°C) is associated with the loss of weight on the TG curve.



# What is Metakaolin? -- Structural characterisation

XRD shows the disappearance of the crystalline structure of kaolinite. The structure of metakaolin is amorphous.



# What is Metakaolin? -- Structural characterisation

$^{27}\text{Al}$  NMR shows the presence of  $\text{Al}_V$ , a five-coordinate species. This species is very reactive and is characteristic of metakaolin.

	Kaolinite	Metakaolin
<b>Structure</b>	<ul style="list-style-type: none"> <li><math>\text{Al}^{3+}</math> in octahedra.</li> <li><math>\text{Si}^{4+}</math> in tetrahedra.</li> </ul>	<ul style="list-style-type: none"> <li>Destruction of <math>\text{Al}^{3+}</math> octahedra.</li> <li><math>\text{Si}^{4+}</math> in a polymer of tetrahedra.</li> </ul>
<b><math>^{27}\text{Al}</math> NMR</b>	<ul style="list-style-type: none"> <li><math>\text{Al}_{VI}</math> signal (-3 ppm).</li> </ul>	<ul style="list-style-type: none"> <li><math>\text{Al}_{VI}</math> transforms into <math>\text{Al}_{IV}</math> (70 ppm) &amp; <math>\text{Al}_V</math> (35 ppm).</li> </ul>
<b><math>^{29}\text{Si}</math> NMR</b>	<ul style="list-style-type: none"> <li><math>\text{Si}_{IV}</math> signal (-90 ppm).</li> </ul>	<ul style="list-style-type: none"> <li>“metakaolin signal” (-100 ppm).</li> </ul>

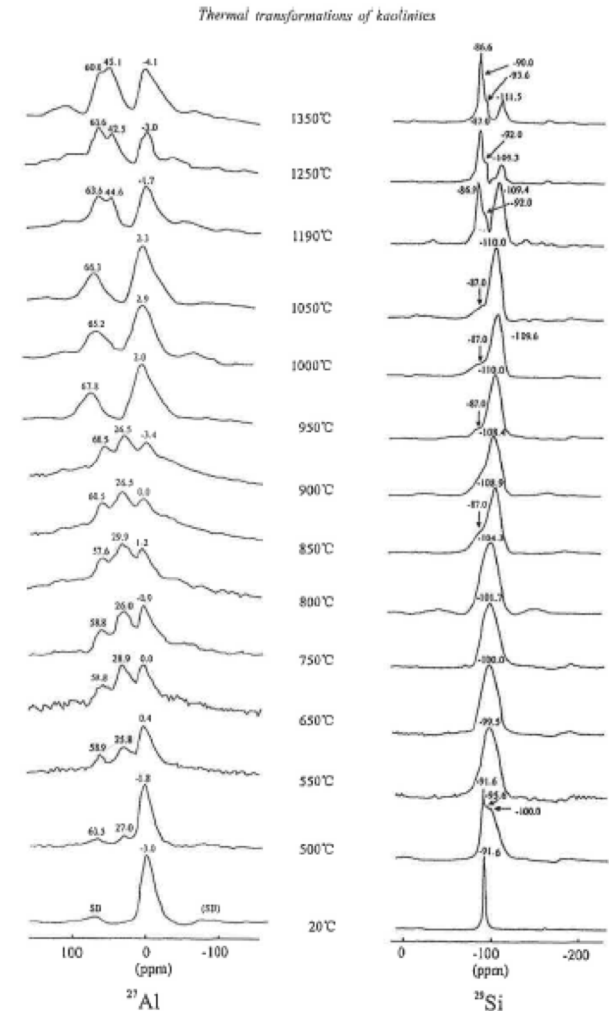


FIG. 3.  $^{27}\text{Al}$  and  $^{29}\text{Si}$  MAS NMR spectra of the kaolinite heated at different temperatures.

# An Introduction to Metakaolins



What is Metakaolin?  
**The Manufacture of Metakaolin**  
The Properties of Metakaolin



# Manufacture of Metakaolin



## Feed Kaolin

- Mining
- Preparation



## Calcination

- Rotary Kiln
- Flash Kiln



## Milling

- Ball Mill
- Hammer Mill
- Roll-press Mill

### Key performance factors

- Mineralogy
- Chemistry
- Specific Surface

### Key performance factors

- Time
- Temperature
- Redox conditions

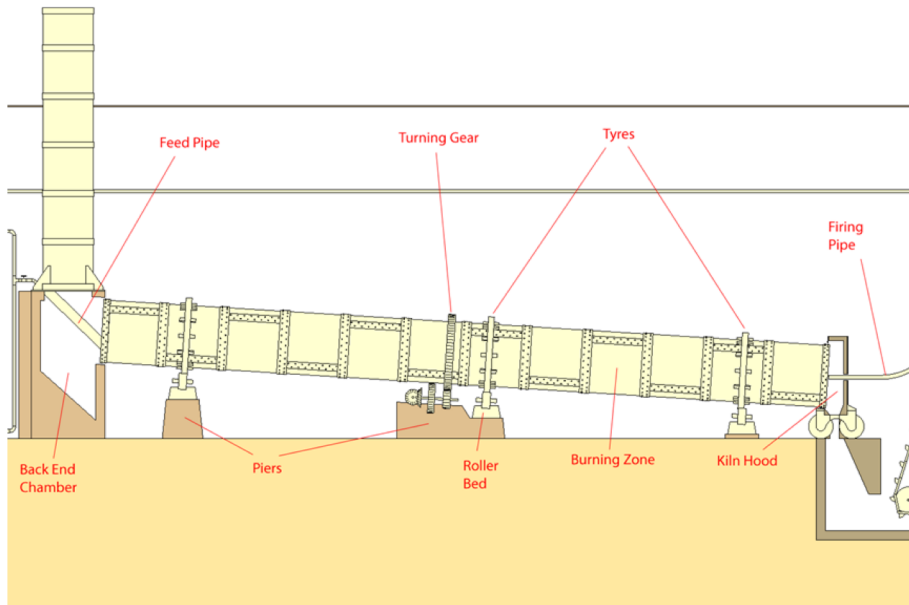
### Key performance factor

- Particle size

# 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 or 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)

# Manufacture of Metakaolin: Rotary Kiln



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

Residence time:  
4 hours

Rotary kiln at Imerys Refractory Minerals  
Clérac (France)

L= 34 m;  $\varnothing$  2,5 m

Throughput: 10 tonnes per hour

Fuel oil + Biogas + Sawdust

# Manufacture of Metakaolin: 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.

## Product available:

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

# Manufacture of Metakaolin: Herreshoff Kiln

## Advantages

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

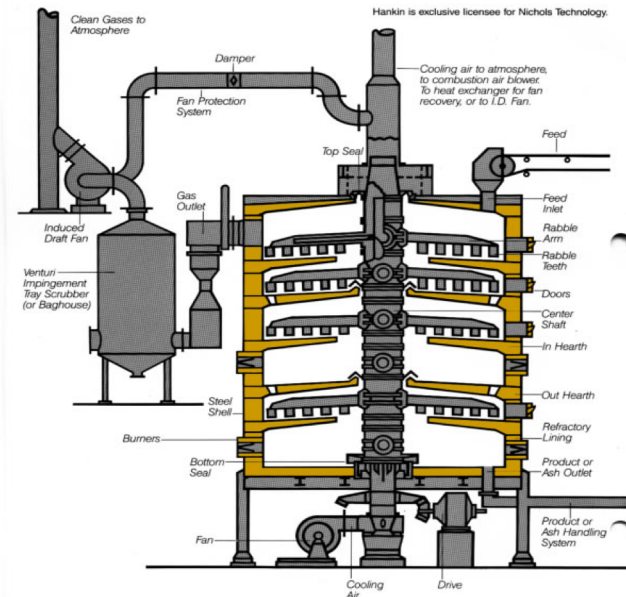
Residence time:  
40 -- 60 minutes

Product available:

❖ METASTAR 501 (USA)

## 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.



# Manufacture of Metakaolin: Flash Kiln

## Advantages

- Really flexible: Target temperature quickly reached.
- Precise control of temperature, 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).

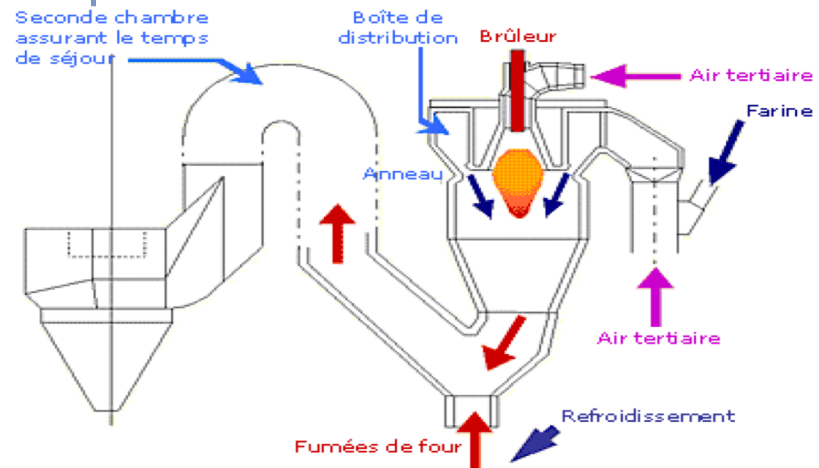
Product available:

❖ ARGICAL M-1200S (France)

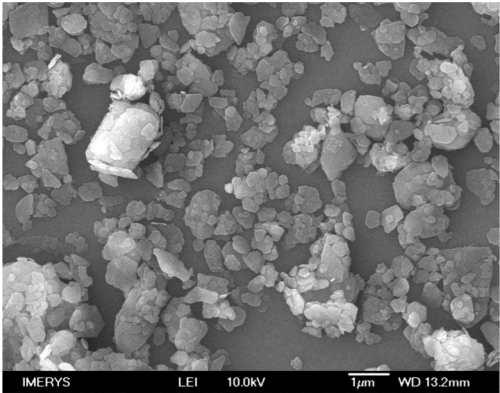
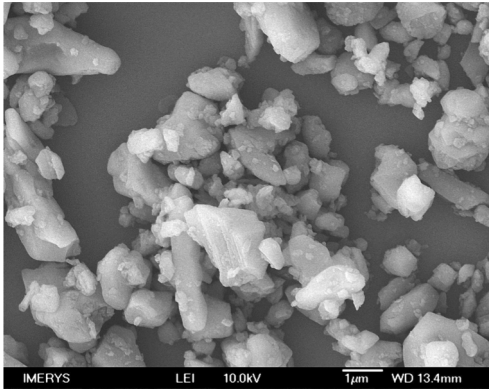
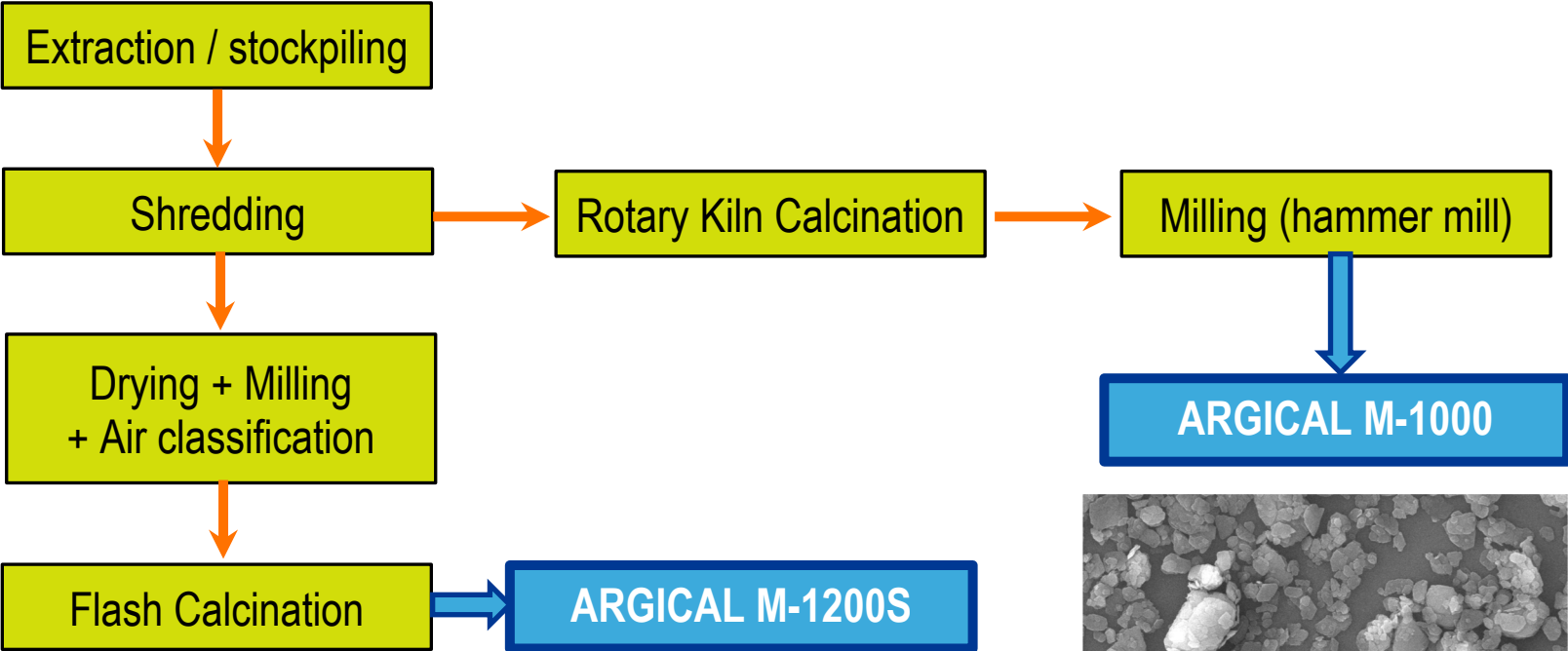
## Drawbacks

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

Residence time:  
less than 1 second



# Manufacture of Metakaolin: Imerys Clérac



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**The Properties of Metakaolin**



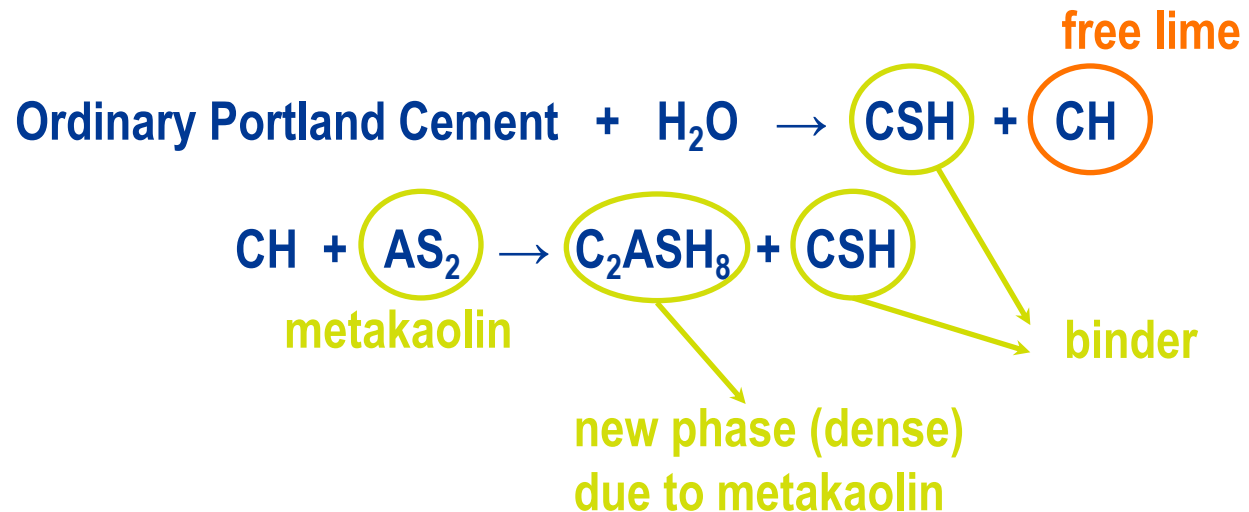
# Properties of Metakaolin: Pozzolanic Activity

- Pozzolans are inorganic material composed mainly by rich siliceous or silico-aluminous amorphous phases.
- Pozzolans themselves possess no binder properties.
- In the presence of water, pozzolans chemically react with calcium hydroxide to produce compounds with binder properties.



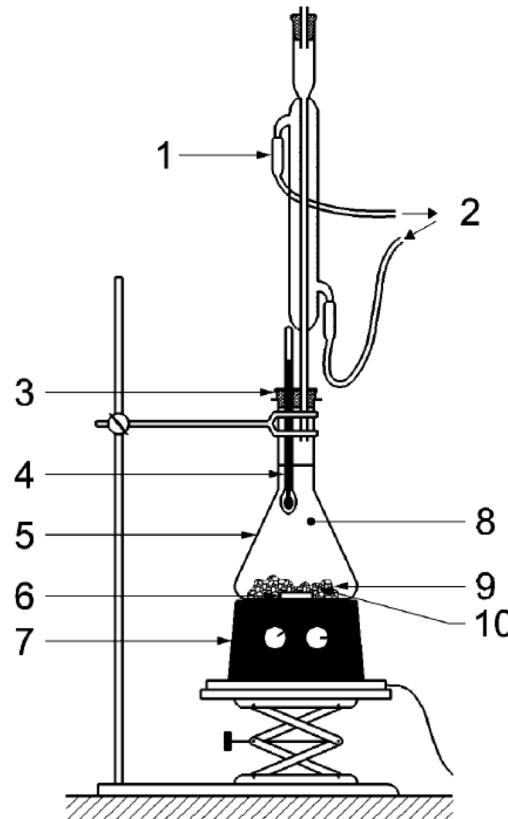
# Properties of Metakaolin: Pozzolanic Activity

- 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 cementitious materials, metakaolin reacts with the lime released by the cement during its hydration; it also reacts with the lime added in some mortars.
  - ◆ Pozzolanic reaction:



# Properties of Metakaolin: Pozzolanic Activity

- On a day-to-day basis, the pozzolanic activity is measured via the **modified Chapelle test**.
- It is an indirect measurement, based on the consumption of  $\text{Ca}(\text{OH})_2$  in a saturated water medium.



- 1: Condenser
- 2: Circulation of water
- 3: Stopper with 2 holes
- 4: Thermometre
- 5: Stainless steel erlanmeyer
- 6: Magnetic stirring bar
- 7: Heating plate with magnetic stirrer
- 8: CO<sub>2</sub>-free distilled water
- 9: CaO (2g)
- 10: Metakaolin (1 g)

# Metakaolins from Imerys

	MetaStar 501	ARGICAL M-1200S	ARGICAL M-1000	MK-40
<b>Origin</b>	USA	France	France	Ukraine
<b>Calcination</b>	Herreshoff kiln	flash kiln	rotary kiln	rotary kiln
<b>Pozzolanic index [mg Ca(OH)<sub>2</sub> / g]</b>	1400	1400	1100	1000
<b>Surface area (BET) [m<sup>2</sup>/g]</b>	14	23	20	15
<b>D50 [μm]</b>	1.0	1.5	6.0	20.0
<b>Brightness</b>	85	72	69	65



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



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