BRUCITE, HUNTITE AND HYDROMAGNESITE: SUPPLY AND MARKETS

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Blue brucite crystal, South Africa
Acknowledgements

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Mac McCreless

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Professor Wen Lu

Chengdu, China

Rocky Wu

Ismene and Mike
AGENDA

- Brucite,
  - Russia, Russian Mining Chemical Company
  - China, Liaoning
  - Others – USA
  - Markets
- Hydromagnesite and Huntite
  - Turkey – LKAB, Likya Minerals
  - Greece – Sibelco Hellas S.A. Mining Company
  - Markets
MAGNESIUM HYDROXIDE
BRUCITE $Mg(OH)_2$

MAGNESIUM CARBONATES
HUNTITE $(Mg_3Ca(CO_3)_4$
HYDROMAGNESITE $Mg_5(CO_3)_4(OH)_2\cdot4H_2O$

MAGNESITE $MgCO_3$
BREUNNERITE $(Mg,Fe)CO_3$
DOLOMITE $CaMg(CO_3)_2$
CHEMISTRY OF BRUCITE, HUNTITE AND HYDROMAGNESITE

BRUCITE: Mg(OH)$_2$

HYDROMAGNESITE: Mg$_5$(CO$_3$)$_4$(OH)$_2$3H$_2$O

Magnaite: MgCO$_3$

HUNTITE: Mg$_3$Ca(CO$_3$)$_4$
Brucite formation

Mechanism for brucite formation is when dolomitic-marble, or Mg-bearing limestone, is subject to contact metamorphism. Periclase (MgO) is formed and hydrates to brucite in the presence of water.

\[
\text{CaMg(CO}_3\text{)}_2 \quad \rightarrow \quad \text{CaCO}_3 + \text{MgO} + \text{CO}_2
\]

declared as dolomite calcite periclase

\[
\text{MgO} + \text{H}_2\text{O} \quad \rightarrow \quad \text{Mg(OH)}_2
\]

declared as periclase brucite
## Some brucite deposits and resources (MT)

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>COMPANY</th>
<th>DEPOSITS</th>
<th>RESOURCES (MT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHINA</td>
<td>16 COMPANIES</td>
<td>MAINLY FENCHENG, AND KUANDIAN, LIAONING</td>
<td>26</td>
</tr>
<tr>
<td>N. KOREA</td>
<td>NORTH KOREAN</td>
<td>GIL ZU, YANGGANG</td>
<td>2</td>
</tr>
<tr>
<td>RUSSIA</td>
<td>RUSSIAN MINING CHEMICAL COMPANY (RMCC)</td>
<td>KULDUR SAVINSKY</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>USA</td>
<td>BRUCITE INTERNATIONAL CORP (BRUCITIC MARBLE)</td>
<td>VAN HORN, TEXAS</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>PREMIER MAGNESIA LLC</td>
<td>GABBS, NYE COUNTY, NEVADA</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>70</td>
</tr>
</tbody>
</table>
Russian Mining Chemical Company

- Holding company of the RMCC Group
- Headquarters located in the centre of Moscow
- Sales for most products of the Group
- Providing technical sales support
- Develop marketing strategy of RMCC Group
COMPANY STRUCTURE

Russian Mining Chemical Company

Kuldur Mine
- Mining of raw materials
- Material selection
- Quality control

Vyazma Brucite Plant
- Incoming quality control
- Milling
- Classification and quality control

Europiren B.V.
- Sales in Europe
- New plant in the Netherlands
- Polymer lab in Rotterdam
RUSSIAN MINING CHEMICAL COMPANY

Vyazma Brucite Plant

JEWISH AUTONOMOUS OBLAST

Kuldar Brucite Mine
Savinsky Deposit

RUSSIA
• Products are made from high quality magnesium hydroxide
• Chemical Formula of Brucite: $\text{Mg(OH)}_2$
• Pure mineral composition: $\text{MgO} - 69.12\%; \text{H}_2\text{O} - 30.88\%$
• Crystal System: Hexagonal, Rhombohedral, Hardness: 2.5, SG 2.34
• Of industrial magnesium minerals brucite has the highest % Mg content than other raw materials. Low levels of silica, iron and manganese
• RMCC has two of the largest brucite deposits in the world in Russia
Milestones from 2002-2017

- 2002 – RMCC (Russian Mining Chemical Company) was established
- 2006 – Start up of production plant in Vyazma (Smolensk Oblast)
- 2006 – Purchase of blocking share holding of the Kuldur brucite mine
- 2010 – Kuldur Mining Company established
- 2011 – Start up of the new plant in Vyazma
- 2012 – Purchase of the controlling block of shares of the Kuldur mine
- 2013 – Europiren B.V. established in Rotterdam
- 2015 – Start of polymeric laboratory in Rotterdam
- 2017 – Acquisition of the mining rights for the Savinsky deposit
RMCC has two deposits of Brucite

**Kuldar brucite mine**
- Reserves of Brucite 10 MT
- 200,000 tonnes mined each year
- Control of shares of mine in 2012
- Local crushing of barite ore

**Savinsky brucite deposit**
- Savinsky deposit acquired in Jan 2017
- Reserves/resources of 22 MT
- Area of the mine 4.09 km²
- Possible to ship 500,000 MT per annum
Kuldur Mining Company

• A programme of re-equipment of the Kuldar deposit with total cost of 5 million Euros.

• The new crushing and sorting complex is operational. The process sorts ore up to 67% of MgO

• Introduction of X-Ray separation separates brucite on the basis of %MgO, SiO₂ and Fe₂O₃

• A fully equipped laboratory for quality control
KULDUR MINING COMPANY - PRODUCTION SCHEME

MINING          LOADING TRUCK         CRUSHER
CONVEYOR
XRF SEPARATION

QUALITY CONTROL

CRUSHING

QUALITY CONTROL

SCREENING PLANT

SHIPMENT OF BEST FRACTION (apr. 45%) TO VYAZMA PLANT

TRANSPORTATION

FINISHED LOW MAGNESIA PRODUCTS (FLUMAG, ORE)

LOWER QUALITY BRUCITE MAINLY AGGREGATES

SHIPPING TO CUSTOMERS

MINING

LOADING TRUCK

CRUSHER

CONVEYOR

KULDUR MINING COMPANY - PRODUCTION SCHEME

MAGFORUM 2017
# RMCC BRUCITE LUMP GRADES (%)

<table>
<thead>
<tr>
<th>ORE GRADE</th>
<th>MgO</th>
<th>CaO</th>
<th>SiO$_2$</th>
<th>Fe$_2$O$_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRADE 1</td>
<td>min 64-64.5</td>
<td>2.5 max-2.0</td>
<td>1.5 max-1.2</td>
<td>0.1-0.1</td>
</tr>
<tr>
<td>GRADE 2</td>
<td>min 62-63.0</td>
<td>3.0 max-2.0</td>
<td>3.0 max-2.5</td>
<td>0.35-0.15</td>
</tr>
<tr>
<td>GRADE 3</td>
<td>min 60-61.5</td>
<td>4.0 max-3.0</td>
<td>4.0 max-3.0</td>
<td>0.50-0.30</td>
</tr>
</tbody>
</table>
Vyazma – Brucite LLC plant

- Brucite processing company of RMCC based in Vyazma (Smolensk) 200 km from Moscow
- Start up of production in 2006 and in 2009-2011 additional equipment was installed to increase sales
- In the production process equipment of leading companies are utilised – Hosokawa Alpine (mill), Spectro (XRF), Lödige (mixer) and Malvern (PSD)
- In January, 2013 the company received the certificate of compliance of quality management system ISO 9001:2008
VYAZMA-BRUCITE LLC – PROCESSING SCHEME

UNLOADING TRAIN HAULER TO CRUSHER BUNKER

CRUSHER + DRYING

CONVEYOR

GASIFIER

MILLING

CLASSIFICATION, BEST FRACTION (apr.30%) FOR EUROPIREN AND REST OTHER PRODUCTS

QUALITY CONTROL

CONVEYOR

MIXER

QUALITY CONTROL

PACKAGING MACHINE BAGS OR BIG BAGS

SHIPMENT TO CUSTOMERS

PACKAGING MACHINE BAGS OR BIG BAGS

CONSISTENCY CONTROL
Total sales of brucite from 2006-2016 (tonnes)

- VYAZMA PLANT START-UP 2006
- NEW PLANT XRF SORTER IN 2011

Yearly sales:
- 2006: 38,714 tonnes
- 2007: 43,351 tonnes
- 2008: 44,455 tonnes
- 2009: 45,346 tonnes
- 2010: 56,302 tonnes
- 2011: 111,749 tonnes
- 2012: 115,867 tonnes
- 2013: 120,812 tonnes
- 2014: 135,536 tonnes
- 2015: 140,536 tonnes
- 2016: 189,500 tonnes
Sales volumes of milled products, kt per year (2013-2016)

% Flame retardants: 15.5% (2013), 22.5% (2014), 26.7% (2015), 31.7% (2016)
## PRODUCTS AND APPLICATIONS

<table>
<thead>
<tr>
<th>Product</th>
<th>Form</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECOPIREN</td>
<td>White powder</td>
<td>Flame retardant in plastics</td>
</tr>
<tr>
<td>AgroMag</td>
<td>White powder</td>
<td>Anticaking agent, magnesium fertilizer, animal feed additive</td>
</tr>
<tr>
<td>BleachMag</td>
<td>Milky white liquid</td>
<td>Pulp bleaching agent</td>
</tr>
<tr>
<td>Agromag Aktimax</td>
<td>Milky white liquid</td>
<td>Horticulture foliage fertilizer</td>
</tr>
<tr>
<td>FluMag</td>
<td>White chip</td>
<td>Foundry flux</td>
</tr>
<tr>
<td>MagTreat</td>
<td>White powder or slurry</td>
<td>Waste water treatment, flue gases adsorbent</td>
</tr>
</tbody>
</table>
Overview of the world markets and applications

- Flame retardants
  - Pulp bleaching
  - Agriculture
  - Water treatment

- Flame Retardants
  - Pulp bleaching
  - Metallurgy
  - Agriculture
  - Water Treatment

- Metallurgy
  - Flame retardants

- Flame retardants

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Europiren B.V.

- Europiren B.V. was established in 2013 based in Rotterdam.
- Main functions of this company are:
  - Sales of products to the European customers
  - Logistic operations with transit loads of products to Asia, America and elsewhere
  - Technical support of customers
  - Post-sales support of customers
  - A production plant is planned in Rotterdam

Rotterdam Science Tower, 18th Floor, Marconistraat 16,
3029 AK ROTTERDAM
New polymer research laboratory in Rotterdam

In 2015 a fully equipped polymer research laboratory in Rotterdam was established. This will help to ensure maximum customer support and assistance in the implementation and use of products.

The new polymeric laboratory aims are:

- Control whole production chain of manufacturing products
- Generate new ideas together with our customers
- Find new solutions and applications in plastics and in close cooperation with customers
- Provide customer support at all stages of production stages
- Execute all necessary laboratory tests

Lab location:
Marconistraat 16, 3029 AK Rotterdam

Rotterdam Science Tower, 18th floor
Decomposition/dehydration temperatures of ATH (alumina trihydrate), huntite/hydromagnesite, magnesium hydroxide and processing temperatures of selected polymers

**POLYMERS**
- Polybutylene terephthalat (PBT)
- Polyamide (PA 6)
- Polypropylene (PP)
- Polyethylene (PE)
- Ethylene vinyl acetata (EVA)
- Polyvinyl chloride (PVC)

*Source: Simandl et al, 2001. Adapted from Georgiades et al., 1995.*
LOCATION OF MAIN BRUCITE DEPOSITS IN LIAONING, CHINA

- XIUYAN
- FENGCHENG
- KUANDIAN

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Brucite in China

- Main deposits is in Liaoning with thirteen mines, ten in Fencheng area, two mines in Kuandian and one in Xiuyan.
- Other deposit are in Shimian (Sichuan), Xixia (Henan) and Qilianzhan (Qinhai) with mainly fibrous brucite. There are other deposits at Ji’an (Jilin) and at Da’an, Ningqiang (Shaanxi) occurring in a serpentized peridotite.
- Most production is in Liaoning. Resources of brucite are estimated at 24.3 MT and capacity around 800,000 tonnes. However, current production is limited due to environmental and other issues.
- The brucite is associated with dolomitic marble and magnesite.
- There is no longer Export Quotas for brucite and from 2011-2016 the quotas varied between 400,000 to 500,000 t. At times not all the quotas were taken up.
Magnesite overlying brucite
Within Dolomitic marble

Brucite within Dolomitic marble and associated
With a granitic intrusion  Crystal size can be
Increased by intrusion of amphibolite dyke
Mining in Liaoning is mainly mined at surface and some underground. The deposits are associated with dolomitic marble and magnesite. Where structure of the deposit is dipping difficult to establish a benching system.

By comparison RMMC, Kuldur, has well established benches for mining of brucite.
## Comparison of Grade 1 Brucite from Russia and China (Wt.%)  

<table>
<thead>
<tr>
<th>BRUCITE COMPANY</th>
<th>MgO (min)</th>
<th>CaO (max)</th>
<th>SiO₃ (max)</th>
<th>Fe₂O₃ (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RUSSIA, RMCC. KULDUR</strong></td>
<td>64.0</td>
<td>2.5</td>
<td>2.5</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>CHINA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XIUYAN, MINIU</td>
<td>64.0</td>
<td>1.0</td>
<td>3.0</td>
<td>0.5</td>
</tr>
<tr>
<td>FENCHENG, JINYUAN</td>
<td>64.0</td>
<td>2.5</td>
<td>2.0</td>
<td>1.0</td>
</tr>
<tr>
<td>FENCHENG, XINDA</td>
<td>64.0</td>
<td>2.5</td>
<td>4.0</td>
<td>2.0</td>
</tr>
<tr>
<td>FENGCHENG, JUNWEI</td>
<td>64.5</td>
<td>1.5</td>
<td>5.0</td>
<td>0.35</td>
</tr>
<tr>
<td>FENCHENG, SHIHOUGOU</td>
<td>60.0</td>
<td>2.0</td>
<td>8.0</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Bruciitc marble (mix of brucite and calcite) was mined by Applied Chemical Magnesias (ACM) at Marble Canyon, Van Horn, Texas. Markets were for wastewater treatment, stucco and animal feed. Following legal issues with the mine ACM-Texas filed for bankruptcy in 2008.

The Marble Canyon operation is now owned by International Brucite Corporation (IBC) which is owned by Texas Architectural Aggregate Inc (TAA) with HQ in San Saba, Texas. The chemistry and mineralogy of the deposit is shown below (source Mac McCreless 2007):

<table>
<thead>
<tr>
<th>Chemical Analysis (wt.%)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg (OH)₂</td>
<td>35.7</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>63.4</td>
</tr>
<tr>
<td>SiO₂</td>
<td>0.17</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>0.11</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.14</td>
</tr>
<tr>
<td>LOI</td>
<td>36.4</td>
</tr>
<tr>
<td>Acid Insoluble residue</td>
<td>0.4</td>
</tr>
<tr>
<td>Moisture</td>
<td>0.3</td>
</tr>
<tr>
<td>Mineralogy</td>
<td>Mix of brucite and calcite</td>
</tr>
</tbody>
</table>
Mac McCreless, Managing Director, set up Garrison Minerals specializing in magnesium based materials in their Hydroxide, Oxide and Carbonate forms

Garrison actively distributes and markets Mg(OH)$_2$ as dry powders and slurry

Brucite, Mg(OH)$_2$ is imported from China into USA and processed with various partners

Garrison has 11 distribution slurry terminals at Austin (TX), Bartow (FL), Chatsworth (GA), Darlington (SC), Denver (CO), Florence (KY), Houston (TX), Oxnard (CA), Sully (IA), Sulphur Springs (TX) and Wellsville (OH)

Cimbar Performance Minerals are a partner with Garrison and utilise their plants at Chatsworth (GA), Houston (TX) and Wellsville (OH) to produce slurry and dry powder

Cimbar produce fine-milled uncoated and surface treated grades – UltraMag, Ultra Mag CM and UltraMag SA.

Source: Mac McCreless, Garrison Minerals
MAGNESIUM HYDROXIDE PRODUCTS
BASED ON BRUCITE

TECHNICAL GRADE SLURRY
pH CONTROL FOR MUNICIPAL/INDUSTRIAL TREATMENT
- 20-55% SOLIDS
- BULK LOADS UP TO 48,000 lbs (WET) PER TRUCKLOAD
- FLEXIBLE ORDER SIZE FROM 5 gal – 4,000 gals +

TECHNICAL GRADE DRY MATERIAL
VARIOUS INDUSTRIES FROM PLASTICS TO POWER GENERATION
- PARTICLE SIZE FROM 5 Mesh (4mm) dpwm to 2 microns
- PACKAGING IN 50 lbs to 2,200 lbs SUPER BAGS

FOOD/PHARMACEUTICAL GRADE
SUITABLE AS A FOOD ADDITIVE OR PHARMACEUTICAL INGREDIENT
- MEETS REQUIREMENT FOR USP FOOD CHEMICALS CODEX
- OFFER IN IN 25kg (55lb) BAGS (custom packaging also available)

Courtesy: Garrison Minerals
• Reserves of huntite and hydromagneiste are found in the Çameli Basin.

• Age is estimated at 2 - 3 million years.

• Resources estimated at 10 million tonnes

• Formation of the deposit is a result of three factors

  1. Depositional area of magnesium rich ultramafic basement rocks
  2. Lake environment which evolve into a basin
  3. Tectonic activity to allow magnesium rich hydrothermal solutions to reach the surface

Source: LKAB website
UltraCarb Products

- UltraCarb is a natural halogen-free fire retardant mineral from a deposit of Hydromagnesite and Huntite. Both minerals are flame retardants on their own but a combination of the two is fine.
- UltraCard is used as a fire retardant filler in a wide range of polymers.
- Next slide shows a three stage fire retardant mechanism of UltraCarb.
1. Water is released at ~220°C (thermal decomposition)

2. CO₂ released at ~330°C

2. At ~560°C UltraCarb particles accumulate at the surface of the burning polymer to form a stable char which inhibits combustion
Hydromagnesite and Huntite

- Hydromagnesite and huntite, along with aragonite, are formed in closed lacustrine basins of Tertiary to recent age.
- The formation of Mg-rich minerals in closed basins is commonly related to an ultramafic and/or dolomite source.
- Two examples of Hydromagnite and huntite operating deposits are in Greece and Turkey. Other occurrences are in British Columbia (Atlin) and Serbia (Bela Stena).
- The main mechanism is the dissolution of the Mg-silicates in the catchments and precipitation of Mg$^{2+}$ in the form of Mg-and/or Mg-Ca carbonates in a closed hydrological system.
- The two operating mines are Sibelco Hellas S.A Mining Company (Greece) and Likya Mining Company (LKAB), Turkey.
HUNTITE-HYDROMAGNESITE MINED AND AFTER PROCESSING HAS A MIXTURE OF 60% HUNTITE: 40% HYDROMAGNESITE

THICKNESS 3-4 metres
MINES: NERAIDA KOZANI
PLANT: LEFKARA KOZANI
RESERVES: 500,000 tonnes
MINING: MAY-SEPTEMBER
HUNTITE – HYDROMAGNESITE MIXTURE

Courtesy: Professor Stamatakis
MINE AND PLAN FOR HYDROMAGNESITE-HUNTITE

Hydromagnesite- Huntite

Mine at Nerida Kozani

Plant at Nerida Kozani
Huntite and Hydromagnesite products

- **Huntite Products / Portafill H5**
  - High brightness 94-96%
  - Low iron (<0.01%)
  - Platy nature
  - Used in paint

- **Hydromagnesite Products/Securoc C10**
  - Used in a mix with plastic materials for insulation of special cables
  - A fire retardant and flame retardant

Courtesy: Prof Stamatakis
## PRODUCTION AND SALES OF HUNTITE-HYDROMAGNESITE 2010-2014 (TONNES)

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCTION</td>
<td>16,350</td>
<td>23,800</td>
<td>24,200</td>
<td>15,220</td>
<td>5,340</td>
</tr>
<tr>
<td>SALES - PROCESSED*</td>
<td>4,467</td>
<td>4,484</td>
<td>7,450</td>
<td>6,908</td>
<td>4,274</td>
</tr>
<tr>
<td>SALES - RAW MATERIAL</td>
<td>5,098</td>
<td>5,897</td>
<td>5,420</td>
<td>2,780</td>
<td>2,700</td>
</tr>
<tr>
<td>TOTAL SALES</td>
<td>9,565</td>
<td>10,381</td>
<td>12,870</td>
<td>9,688</td>
<td>6,974</td>
</tr>
</tbody>
</table>

**SALES OF HUNTITE-HYDROMAGNESITE (60:40%)**

FLAME RETARDANTS IN PLASTICS/WIRES AND PAINT

*Source: Mining & Metallurgical activity in Greece 2013-2014*

THANKS FOR YOUR ATTENTION