

Soaking it up: Bentonite's global reach

By IM Staff

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Recent growth in bentonite consumption has been driven largely by foundry, oil drilling and iron ore pelletising markets. However, the latest downturn in oil and steel prices is likely to see volumes in the latter two markets decrease in the short to medium term. Andrew Scogings* gives an overview of worldwide bentonite production and consumption.

The name *bentonite* was first suggested in 1898 for clay hosted by the Benton Shale in Wyoming. It was initially described as clay formed by the alteration of volcanic ash, but the most widely used commercial definition is that bentonite is clay consisting essentially of smectite minerals (usually montmorillonite) regardless of occurrence or origin.

In geological terms, bentonite is essentially a rock composed of smectite plus variable amounts of impurities, or 'inert minerals' such as quartz, feldspar, kaolinite, illite, gypsum, zeolite, and opaline silica. Interestingly, minerals such as zeolite may complement the smectite component in products such as cat litter, where zeolite helps with odour control.

Most economic bentonite deposits are of Cretaceous age or younger and associated with marine shale and marl (Wyoming), calcareous sands and marls (Morocco), carbonaceous shales and coal (South Africa), sandstone and conglomerate (Australia), dacitic pyroclastics and tuffs (Milos), andesite (China) or rhyolite and obsidian/perlite (China and Mozambique).

Bentonite is characterised by exchangeable cations such as Ca^{2+} , Mg^{2+} , Na^+ or Li^+ which affect its designation and properties. For example, bentonite is typically described as either swelling or non-swelling bentonite. Swelling bentonite (also known as western bentonite) is sodium bentonite that swells in water and is generally used in its natural state. Non-swelling bentonite is calcium bentonite (also known as southern bentonite) that is used as mined, after treatment with soda ash to produce sodium-exchanged bentonite, or treated with acid to produce bleaching clay. Li-rich bentonite is known as hectorite and is commercially mined only in the US.

Bentonite is truly 'a mineral of a thousand uses' and is utilised for its high surface area, bonding, swelling, sorptive, sealing and rheological properties. These properties may be modified by treatment with acids, soda ash or other chemicals in addition to calcination, milling and sieving. Bentonite finds application in diverse markets including metalcasting, oil well drilling, iron ore pelletising ('IOP'), edible oil purification, paper, ceramics, detergents, cat litter and civil engineering.

Global production

Global bentonite production was estimated by the United States Geological Survey (USGS) at 16m tonnes in 2015.

The US and China are the world's foremost bentonite producers and are estimated to account for 50-60% of overall supply, or around 8-10m tpa (*Figure 1*). The main discrepancy in global estimates concerns Chinese production and, whereas the USGS 2013 *Minerals Yearbook Clay and Shale* report doesn't include any Chinese bentonite production for 2013, the USGS 2013 *Minerals Yearbook China*

(Tse, 2015), the USGS *Clays* report (Flanagan, 2016) and the BGS (Brown et al., 2015) each reported approximately 3.5m tonnes for 2013.

According to data from the China Non Metallic Industry Association (CNMIA) China's bentonite production had increased from 4m to 8m tpa by 2014; however the Chinese bentonite industry currently faces difficulties such as low demand and fierce competition mainly in the IOP space. This is because imported lumpy iron ore has reduced demand for IOP-grade bentonite as a binder for Chinese iron ore fines such as magnetite. The CNMIA reported recently that Chinese IOP production was approximately 130m tonnes, consuming some 2.5m tpa of bentonite at an addition rate of about 2% bentonite per tonne of iron ore.

Professor Lei, Suzhou SINOMA Design and Research Institute of the Non-metallic Minerals Industry Co., recently estimated that current Chinese bentonite consumption exceeds the 5m tpa mark, with 2.2m tpa going into the IOP market, 1.5m tpa going into machine casting, 500,000 tpa consumed by drilling muds, 300,000 tpa going into activated clays and the remaining 0.5m tpa being taken up by other, smaller markets.

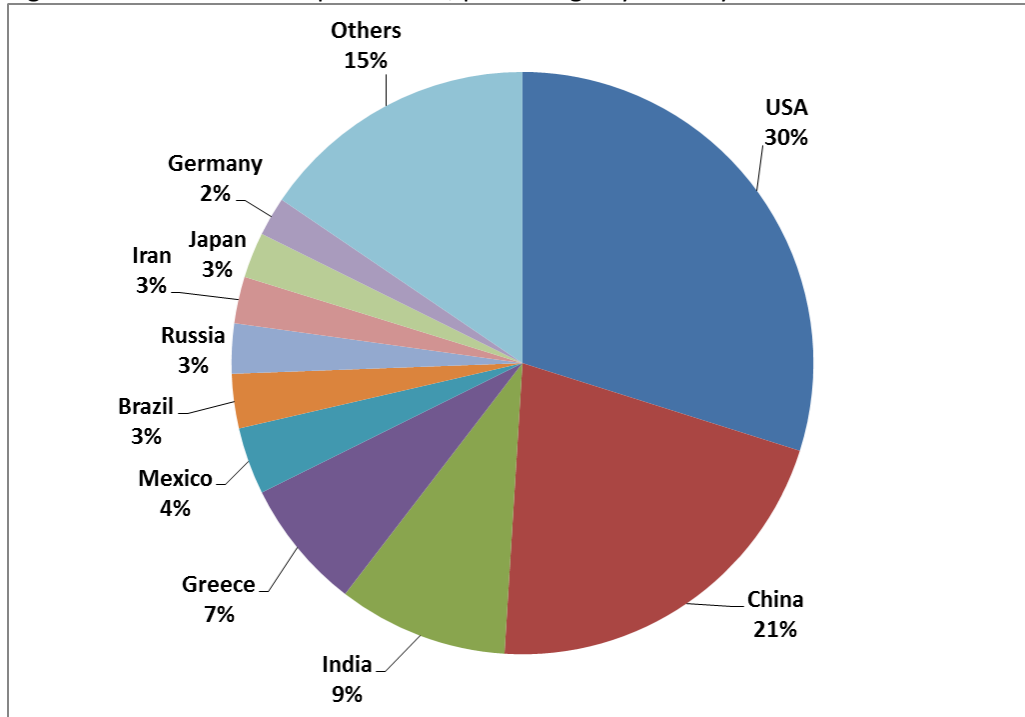
Leading global exporters of sodium and calcium bentonite include India, US and Greece, while leading importers include Canada, Germany, Netherlands and Japan (*Table 2*). The US is the leading global producer of sodium bentonite and is also a significant producer of calcium bentonite. Elsewhere in locations such as Europe, China and India, calcium bentonite is the predominant mineral and is used either in its natural state or after sodium-exchange or acid activation.

Table 1 Bentonite trade by leading exporting and importing countries

		Exports (1,000 tonnes)									
Country	HS Code	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
India	3803	437	415	503	582	440	117	886	973	1,447	1,258
USA	250810	848	1,274	1,432	1,089	710	947	1,029	1,035	892	902
Greece	250810	876	974	1,119	1,177	746	992	1,007	931	920	850
Turkey	250810	238	293	279	244	250	308	319	338	394	370
Italy	250810	247	274	298	281	187	242	215	226	225	236
China	250810	254	286	319	368	255	321	193	194	215	219
Slovakia	250810	76	118	99	94	73	33	87	98	185	160
Netherlands	250810	186	132	130	121	136	178	187	142	137	121
		Imports (1,000 tonnes)									
Country	HS Code	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Canada	250810	384	491	560	443	354	486	459	539	467	476
Germany	250810	319	411	352	362	336	386	448	435	489	475
Netherlands	250810	200	281	305	314	84	238	290	277	216	264
Sweden	250810	49	125	184	178	120	200	214	232	190	238
Poland	250810	115	154	165	175	122	156	208	227	209	191
Japan	250810	204	223	210	253	122	201	211	246	202	185
UK	250810	152	186	160	197	143	137	200	174	173	152
Brazil	250810	168	138	221	216	124	205	197	160	128	116
Thailand	250810	50	50	39	54	42	65	104	83	103	101

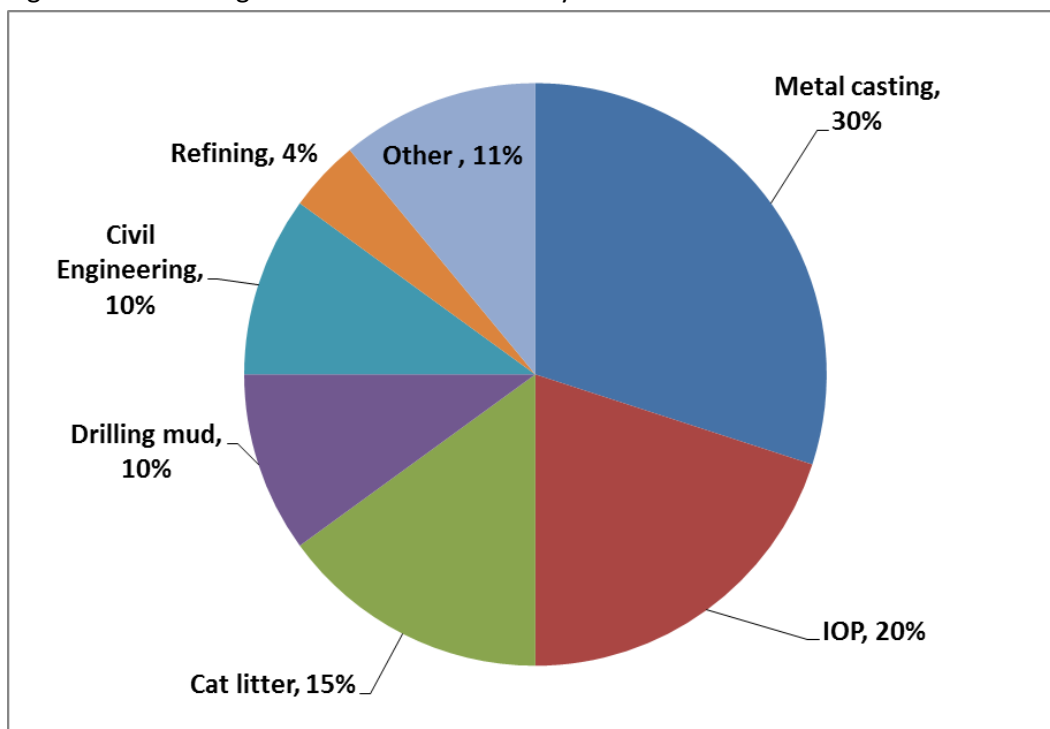
Source: UN Trade Statistics

Figure 1 Global bentonite production, percentage by country in 2013



Source: BGS (Brown et al., 2015)

Figure 2 Estimated global bentonite demand by market



Source: BGS, industry sources, Shaw (2014)

Global consumption

The main bentonite markets are foundry, cat litter, IOP, drilling mud and civil engineering which together account for >80% of sales by volume (*Figure 2*). Bentonite markets such as IOP and drilling mud are directly related to steel production and oil/gas drilling activity, both of which have declined in the past year - therefore sales to these markets are believed to have decreased during 2015 and into 2016.

Consumption patterns vary from region to region, depending on the composition of the industrial base and population demographics. For example, cat litter consumption is higher in wealthier economies; therefore demand is concentrated in areas such as North America, Japan and Europe. Similarly, bentonite consumption for iron ore pelletising is greatest in countries that produce iron ore 'fines' that need to be agglomerated, such as in China, Russia and the US.

Foundry sands probably have the widest geographic distribution of bentonite applications; however castings production has increasingly transitioned from high-cost locations such as Western Europe, to lower-cost production bases in Eastern Europe, India, S.E. Asia and China. Conversely, the US remains a major producer of iron castings due mainly to its large automotive and heavy equipment manufacturing industry.

Industrial-grade bentonite prices range from as low as approximately \$30/tonne for cat litter dried crudes to \$220/tonne for foundry-grade dried crudes, according to **IM** data. Other specialised grades for paper, wine fining, detergents and edible oil clarification markets command higher prices.

Exploration and Production methods

Bentonite exploration generally follows a similar path to other minerals, often from discovery of an outcrop, which is then explored by methods such as field mapping, trenching, drilling (*Figure 3*) and lab testing. Data generated in this way, if successful, could lead to the estimation of a mineral resource which defines the geometry, tonnage and quality of a deposit.

Bentonite deposits are often large, shallow dipping and tend to have greater lateral than vertical extent. Most deposits are mined from open pits using bulldozers and scrapers to remove overburden, followed by selective extraction of the bentonite using excavators or front end loaders.

After mining, the clay is often stockpiled or laid out on 'drying pads' to allow for natural drying before blending into product stockpiles (*Figure 3*). Bentonite is typically made into final products via a process of drying, crushing, milling or screening. Some producers supply dry crudes in bulk (also known as 'dried and crushed') to processors who may blend with local bentonite and then mill into final products.

Although bentonites are generally described as being calcium (southern) or sodium (western), in fact a complete range of calcium to sodium varieties exist throughout the world. This even applies to the 'western' bentonites in Wyoming, Montana and South Dakota, which are traditionally described as sodium bentonites. Calcium and magnesium bentonites may be sodium activated and this is usually achieved by the addition of sodium carbonate (soda ash), in the process replacing exchangeable Ca and Mg cations with sodium cations. If bentonite requires additional sodium, soda ash may be added as powder or a solution to bentonite drying pads, or added to bentonite in mixing and shearing equipment such as pan mills, paddle mixers or extruders.

Because of the wide variety of applications in which bentonite is used, there is no optimum level of sodium that meets all requirements, nor is sodium activation always desirable. Therefore as a general rule, bentonites require different levels of sodium activation (typically less than 4% soda ash), depending on the amount of exchangeable calcium and magnesium cations present in the clay and the final properties desired.

The addition of too much sodium, also known as 'over-activation', can result in decreased thermal durability in foundry clays and in increased fluid loss in drilling muds. On the other hand, too little soda ash may result in low swelling, low viscosity and low water absorption which could adversely affect performance in drilling muds and IOP.

Calcium bentonite that is destined for edible oil purification is treated with HCl or H₂SO₄ (acid activation). This treatment removes impurities such as calcite, replaces exchangeable cations with hydrogen and opens up the clay platelets to increase the surface area.



Figure 3 MTI drying pads, stockpiles and plant at Colony, Wyoming
Source: Google Earth™

Leading global bentonite producers

AMCOL International was acquired by Minerals Technologies Inc. ('MTI') in 2014 and is the leading producer, accounting for an estimated >15 % of global bentonite production, most of which is produced in the US in Wyoming (Colony and Lovell) and Alabama (Sandy Ridge). MTI also produces bentonite from mines and plants in Australia (Gurulmundi), China (Jianping area), Mexico and Turkey (Enez area) and in addition has plants in other countries including Australia, China, India, Poland, South Korea, Thailand and UK where imported and / or local bentonite is processed. MTI has numerous blending plants in the US where specialised foundry blends are produced; these products are known as Additrol® which are custom bentonite blends that may also include carbonaceous products, cereals, iron oxides and starches. MTI supplies most bentonite markets and also has plants producing geosynthetic clay liners in the US, Poland and other global locations.

Imerys acquired S&B Industrial Minerals in 2015 is considered to be the second largest bentonite producer in the world, with an estimated 10-12% market share in volume terms. The S&B acquisition

brought numerous mineral assets to the company, including bentonite, perlite, and wollastonite. Imerys now has bentonite mines and plants in Greece (Milos), Bulgaria (Propast, Dobrovoletz and Enchetz mines in the Kardzhali area), Hungary (Egyhozasheszo), Georgia (Mtspiri mine in the Ozurgeti area), Morocco (Trebja mine in the Nador area), South Africa (near Heidelberg), USA (Tennessee), India and China (Jianping area). Imerys supplies many different applications such as foundry, iron ore pelletizing, civil engineering, drilling fluids, pet litter, animal feed and other specialities.

Clariant AG bought private equity-owned Süd-Chemie AG in April 2011 to expand into chemical catalysts used in the oil and automotive industries. Süd-Chemie was a long established German-based global producer of industrial grade bentonites, catalysts and specialised bentonite-based products for markets including metal casting, civil engineering, drilling, paper, detergents, edible and non-edible oils, fat and wax purification. Clariant has bentonite mining and production facilities in several countries including China, Germany, Indonesia, Mexico and Turkey.

The Taiko Group, based in Malaysia, is reportedly the largest producer of bleaching earths after Clariant. Its operations include mining and processing in China, India, Indonesia and Malaysia.



Figure 4 Sodium bentonite (2 metres thick) overlain by tuff and sandstone. Gurulmundi, Australia
Source: MTI



Figure 5 Calcium bentonite overlain by andesite. Jianping, Liaoning Province, China
Source: A. Scogings

Bentonite production in selected countries

Examples of bentonite production in selected countries are outlined below. These examples are not an exhaustive list, but aim to highlight some global activities across a spectrum of locations and bentonite types.

Australia is estimated to produce between 100,000 and 200,000 tpa of bentonite from four mines. Sodium-magnesium bentonite is mined in New South Wales near Mildura (Arumpo Bentonite) and near Gurulmundi north of Miles in Queensland (MTI and Sibelco). MTI's Gurulmundi mine has several sodium bentonite beds ranging up to three metres in thickness and varying in colour from blue grey, olive grey, greyish yellow green to yellowish grey. Each bed is characterised by a distinctive mineralogical and chemical fingerprint, but in the main they consist of montmorillonite associated with variable amounts of other minerals including zeolite and feldspar. The bentonite beds are often capped by volcanoclastic rocks such as tuff or volcanogenic sandstone (*Figure 4*) and products are supplied to foundry, drilling, civil engineering, cat litter, agriculture and other markets both locally and overseas.

Calcium-magnesium bentonite was previously mined near Scone in New South Wales and a significant deposit of calcium bentonite at Mantuan Downs in northern Queensland was discovered in the 1960s; this was mined on a trial basis within the last few years by Australian Pacific Coal Ltd. Sodium-magnesium bentonite has been produced during coal mining operations near Ipswich, west of Brisbane and the stockpile is currently processed by Bentonite Products Pty Ltd for supply to civil engineering markets amongst others.

China is probably the leading global producer of bentonite, though estimates vary widely from 3.5 m tonnes (USGS; BGS) to between 4 and 8 m tonnes (CNMIA) of which a large proportion goes into iron ore pelletising. Most Chinese bentonite is calcium dominant; a wide range of colour and purity means that a wide range of markets can be supplied, from IOP, foundry, civil engineering and drilling through to desiccants, oil purification, paper and detergents.

The main source of industrial grade bentonite in China for foundry, civil engineering and drilling markets is near Jianping in western Liaoning Province, where international companies MTI, Clariant and Imerys have mining, processing and distribution facilities. The bentonite is predominantly calcium-magnesium type and usually associated with andesite, sometimes in very thick beds (*Figure 5*). The low iron (off-white to pale yellowish) clays from this area are noted for high thermal durability after soda ash treatment. White bentonite is mined and processed in several provinces including Anhui (*Figure 6*), Hebei and Inner Mongolia for specialised paper and detergent markets.

India produces well in excess of 1m tpa calcium and sodium bentonite and is recorded as exporting about 1m tpa, being a leading supplier to global IOP markets. There are numerous bentonite producers including Ashapura, Gimpex and Star Bentonite, with the majority of India's bentonite sourced from deposits in Gujarat State in western India.

Star Bentonite was founded in 1979 and has numerous mines in Lakhpat, Mandvi and Abdasa counties in Kutch, western Gujarat and processing centres at Bhuj, Faradi and Gandhidham. The company claims to handle a volume of approximately 250,000 tpa, with total capacity of 250,000 tpa lumpy (dried and crushed) and 100,000 tpa milled powders for export. Star recently moved from field activation (spreading soda ash in solution onto bentonite) to automated activation, so that the process includes mixers, blenders, pug mills and extruders in addition to roller mills and rotary driers.



Figure 6 White calcium bentonite associated with rhyolite. Anhui Province, China

Source: A. Scogings

Italy was recorded by the USGS as producing about 100,000 tpa of bentonite in 2013, down from 500,000 tonnes in 2005. Exports are reportedly more than 200,000 tpa, therefore it is considered likely that Italian annual production is a lot higher than recorded by the USGS and BGS. Italy has a number of bentonite producers including long-established Laviosa Chimica Mineraria which mines and processes over 250,000 tons of materials every year. Laviosa markets into a broad range of applications, both for industrial markets (e.g. paint additives, paper industry, detergents, ceramics, plastics, civil engineering, foundry and waterproofing in the environmental and construction sectors) and for the consumer market (cat litter) in more than 80 countries worldwide.

The company has three plants in Italy; two in Livorno and one near Cagliari in Sardinia. Laviosa has several foreign subsidiaries which are in Turkey (Laviosa Sanayi ve Ticaret Ltd.Sti., 100% owned), India (Laviosa Trimex Industries Pvt. Ltd., a joint venture, 55% subsidiary, in partnership with the Indian company Trimex Industries) and France (Laviosa MPC SAS, 80% owned). The Bakirgoel deposit in Turkey has a resource of around 2m tonnes of white and pink bentonite and was opened in August 2015, ready to extract 10,000 tonnes for the year (*Figure 7*). In addition to its own operations, Laviosa holds a stake in the Spanish bentonite processor Laviosa Promasa SA and, in 2014, it took a minority share in Zhejiang Hongyu New Materials, a leading Chinese producer of organoclays. Laviosa continues to make significant investments in order to secure 60% of its raw material requirements for the next 15 years, with the goal of reaching reserves of at least 3 million tonnes.

Japan is a significant producer of around 400,000 tpa calcium and sodium bentonites most of which is consumed domestically and supplemented by imports of about 200,000 tpa. Kunimine Industries and Hojun Kogyo are the two main miners and producers of industrial products that are sold into foundry and civil engineering markets, while Mizusawa industrial Chemicals is an important producer of acid activated bentonite (under the Galleon trademark) for refining edible oils. Kunimine is the biggest Japanese bentonite producer with an output of 150,000 to 200,000 tpa of calcium, sodium and sodium-calcium bentonites from five mines known as Tsukinuno, Kawasaki, Dobuyama, Hosogoe and Shirosaki (*Table 2; Figure 8*). The bentonite is mined both underground and

from opencast pit. Kunimine imports sodium bentonite from Black Hills Bentonite, Wyoming, for blending with their local production.



Figure 7 Laviosa’s white bentonite mine at Bakirgoel near Unye in the Black Sea area, Turkey

Source: Laviosa Chimica Mineraria

Table 2 Geology of Kunimine Group mines

Mine Name	Tsukinuno	Kawasaki	Dobuyama	Hosogoe	Shirosaki
Prefecture	Yamagata	Miyagi	Miyagi	Niigata	Niigata
Geological Age	Miocene	Miocene	Miocene	Miocene	Miocene
Geological origin	Diagenesis	Diagenesis	Hydrothermal /Diagenesis	Hydrothermal	Hydrothermal
Ore Shape	1-7m bedded	20-30m bedded	Massive	Massive	Massive
Bentonite Type	Sodium	Calcium-sodium	Calcium	Sodium-calcium	Sodium-calcium

Source: Masakazu Ito, Kunimine Industries

Russia is estimated to produce about 0.5m tpa calcium bentonite mostly for local consumption. The leading producer is LLC Bentonite Company which has mining operations at the 10th Khutor calcium bentonite deposit near Abakan in Khakassia eastern Russia (*Figure 9*), at the Zryanskoje calcium bentonite deposit near Kurgan in central Russia and at the Dash-Salakhly sodium bentonite deposit near Qazakh in western Azerbaijan. Bentonite reserves are claimed to exceed 35m tonnes in Russia and 86m tonnes in Azerbaijan.

LLC Bentonite supplies markets including foundry, IOP, cat litter, civil engineering and drilling and sales have reportedly grown from 45,000 tonnes in 2001 to more than 450,000 tonnes in 2015. The company estimates that it supplies 75% of the Russian market overall, with 96% share in metallurgy (IOP), 34% in drilling and 74% in metalcasting.



Figure 8 Kunimine's opencast sodium-calcium bentonite mine at Shirosaki
Source: Kunimine Industries Co Ltd



Figure 9 Mining operations at LLC Bentonite Company's Khakasia deposit near Abakan in Russia
Source: LLC Bentonite Company

South Africa and **Mozambique** are estimated to collectively produce about 200,000 tpa bentonite. G&W Mineral Resources ('G&W') mines and activates high purity calcium-magnesium bentonite from a large deposit near Koppies (*Figure 10*) while Imerys mines sodium bentonite near Heidelberg in the Western Cape, South Africa. Products from both mines find their way into a wide spectrum of markets including foundry, civil engineering, drilling and chromite pelletising. Midden Mining was

reported earlier in 2015 to have identified sodium bentonite east of Heidelberg, in the Mossel Bay district.

Calcium bentonite derived from the alteration of obsidian (volcanic glass) within a rhyolitic sequence is currently mined by G&W in southern Mozambique. A mine and milling plant previously owned by G&W is now operated by Mimoc, while Namaacha Mining Limitada has delineated a deposit estimated at >0.5m tonnes north of Mimoc's operation. Namaacha Mining recently conducted trial mining (*Figure 11*) and a bulk sample was successfully tested on a plant scale at a South African chromite pelletising plant. Most Mozambique bentonite is sold into the chromite pelletising market.



Figure 10 Calcium bentonite being mined from G&W's Blaaubosch pit at Koppies, South Africa
Source: G&W Mineral Resources



Figure 11 Trial mining of calcium bentonite at Namaacha Mining's project in Mozambique
Source: Namaacha Mining

The **US** is the leading global producer of sodium bentonite and although significant tonnages are exported, a large part is consumed locally by foundries, oil drilling, IOP and cat litter markets. Calcium bentonite is sold into a range of markets including foundry and acid activated bleaching earth. The largest sodium bentonite producers are MTI, Bentonite Performance Minerals, and Black Hills Bentonite and Wyo-Ben.

MTI is the world's largest producer of sodium bentonite from mines and plants at Colony and Lovell, Wyoming which supply cat litter, drilling muds, IOP, foundry and other applications. MTI is a world leading supplier of high-durability bentonite blends for foundry greensands and also produces calcium bentonite at Sandy Ridge, Alabama.

Bentonite Performance Minerals, a subsidiary of Halliburton, began its history in 1928 and mines and processes sodium bentonite at Colony and Lovell, Wyoming.

Black Hills Bentonite LLC is controlled by the Thorson Family, with the rest of the ownership divided amongst The Clorox Company, Kunimine Industries and Sojitz Corporation. Black Hills Bentonite operates mines and plants near Kaycee, Tensleep and Upton, Wyoming that produce a variety of natural sodium bentonite products for use in cat litter, drilling muds, IOP, foundry and other applications.

The US is unique in commercial production of Hectorite from two localities. The major producer is Elementis Specialties which has been a global supplier of high performance drilling mud products to the oil services industries since 1949. The company mines and processes white hectorite at Hector, California, producing clay and polymeric additives under the Bentone® and Thixatrol® trade names. Hectatone Inc., a wholly-owned subsidiary of Western Lithium USA Corporation, reportedly shipped its first Li-hectorite based drilling grade product known as Hectatone™ in early 2015. The plant sources hectorite from the Kings Valley deposit, Nevada.

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