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BENTONITE DEPOSITS IN AFRICA

This investigation has been carried out through literature surveys in a number of swedish, british, american, french and german databases an by the helpful assistance of the Geological Survey of Sweden. The British Geological Survey in London has also been consulted and a proposition from them is to be found in enclosure /7/.

Bentonite world production

Bentonite is a plastic clay wich easily absorbs water. It is created through the deterioration of volcanic ashes.

Larger deposits outside Africa are to be found in several parts of the world. In 1978 the world production was recorded to 6 529 465 metric tons and in 1980 the figure was 6 426 598 tons out of wich African production counted for some 100 000 tons. The USA alone acounts for about 60% of the world production. See enclosure /1/ "Bentonite - a review of world production", Industrial Minerals October 1982. Another source (enclosure /2/ "Mineral trade notes July 1979, p 9) gives the world production figure for 1978 to 5 341 000 tons.

African bentonite deposits

On the African continent the Republic of South Africa and Algeria are the largest producer nations, but there are also production in Egypt, Morocco, Mozambique and Tanzania. Deposits are also reported in Kenya, Sudan and Madagascar as well as in several areas of South-west Africa although ther is not clear wether there is any actual production in theese countries at present.

Production of bentonite in Africa (tons) acording to Industrial Minerals October 1982.

	1977	1978	1979	1980
Algeria	24 337	35 664	36 000[e]	36 000[e]
Egypt	3 811	3 488	5 085	5 200
Morocco	4 807	4 800	1 015	3 284
Mozambique	2 744	3 000	1 656	1 500[e]
South Africa	37 221	34 519	46 394	51 815
Tanzania	35	20	80[e]	80[e]

e-Estimate

A more detailed description including some companies involved is included in the article in enclosure /1/.

Grim and Güven states in the introduction to their book "Bentonites" (1978) that although they doesn't claim to cover all known deposits of bentonite world wide it is hoped that no large significant deposit is overlocked. For Africa Grim and Güven records bentonite occurences in Algeria, Morocco, Union of South Africa and Mozambique. Short notices including literature references are also given concerning Egypt, Kenya, Tanzania and Sudan.

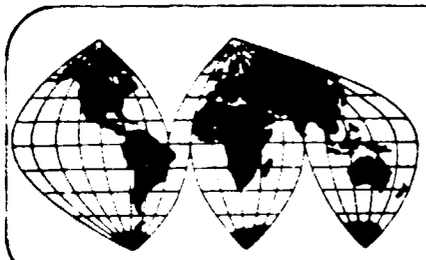
It is stated that bentonites are also known in several areas in Southwest Africa but no further details are given. In a table on page 63 locations of some bentonite deposits in Africa are given. Literature references on page 75. See enclosure /3/.

A short article concerning a new bentonite deposit in South Africa is enclosed /4/.

Some further references are also enclosed /5/.

A copy from Industrial Mineral Index October 1983 concerning articles in that journal dealing with bentonite as well as country and area surveys is enclosed /6/.

A letter from the British Geological Survey is found in enclosure /7/.



Bentonite — a review of world production

by Gerry Clarke, Deputy Editor

The world's bentonite industry is dominated by a number of US companies such as American Colloid, Dresser, Federal Bentonite, NL, Oil Dri, and Wyo-Ben all of which exert their influence in overseas markets to a greater or lesser extent through export tonnage and or subsidiary operations, particularly in Europe. Production in other countries is characterised by a mixture of major companies such as Sud-Chemie in West Germany and Carlo Laviosa in Italy, and smaller scale operations in the hands of a large number of producers. This article focuses on the production of bentonite worldwide and incorporates a tabular summary. Next month a review of bentonite markets will be presented.

Well over 100 companies spread through more than 38 countries were actively engaged in the production of 6.43m. tonnes of bentonite and 1.70m. tonnes of fuller's earth in 1980 — down from the peak 1979 figures of 6.70m. and 1.73m. tonnes respectively in the face of the oncoming recession throughout western markets. The accompanying tables record world production figures for bentonite and fulier's earth for the years 1977 to 1980 based on statistics compiled by the Institute of Geological Sciences in London and the US Bureau of Mines in Washington. However, owing to the complex nature of the mineral some further explanation is necessary. Naturally occurring sodium bentonite is produced in the USA as well as some locations in India, South Africa, and Australia, and perhaps one or two other locations, but most other sodium bentonite is produced artificially by reacting natural calcium bentonite with soda ash. Some companies sodium exchange all their calcium bentonite production whilst others react the material with acid or merely market the beneficiated calcium bentonite or perform all three functions. It is virtually impossible to assess exactly how much of each type of bentonite is produced and so the statistics must be regarded as a guide only. To highlight the point UK production is shown as fuller's earth because this is actually what is mined — a calcium bentonite or calcium montmorillonite — but probably well over half the tonnage is sodium exchanged whilst the balance is acid activated or sold as calcium bentonite or plain old-fashioned fuller's earth. More properly therefore a proportion of UK production ought to be listed as bentonite as this is the form in which the material leaves the plant to be marketed, but any such assessment would be less accurate than current practice. Similarly with other country's output the exact amount of bentonite which is sodium exchanged or acid activated is not known. In contrast grades of southern calcium bentonite produced in the USA which are sodium exchanged are included in the category for bentonite. The table for fuller's earth production includes a figure for the USA which consists of the sum of production of attapulgite and calcium montmorillonite and so is not strictly comparable with the figures for the other countries which are exclusively concerned with calcium montmorillonite albeit of varying degrees of purity and quality. The table of fuller's earth sold or used by producers in the USA should serve to clarify the US position although production in Nevada and Utah is withheld in order not to divulge proprietary commercial data.

A further complicating factor is the omission of production figures for certain countries, and in particular West Germany which is believed to be capable of producing 5-700,000 tpa of bentonite of all types from extensive deposits of calcium bentonite in the Bavarian region of the country. Other significant producers for which figures are not available include Canada, Austria, and inevitably China and the USSR. Undoubtedly output from these countries will raise the world production figure by a further 1m. tpa for bentonite.

Estimated world production of bentonite *(tonnes)*

Country	*1977*	*1978*	*1979*	*1980*
North America				
Canada	na	na	na	na
Guatemala	—	2,593	2,650e	2,650e
Mexico	59,169	140,325	169,848	176,028
USA	3,399,716	4,054,446	4,012,772	3,797,295
South America				
Argentina	114,836	106,957	157,382	174,189
Brazil	108,395	167,614	212,503	247,954
Colombia	1,200e	1,200e	1,200e	1,200e
Peru	41,545	37,215	40,800	41,000e
Western Europe				
Austria	na	na	na	na
Cyprus	13,200e	8,500e	7,000e	23,000e
France	8,063	10,144	16,069	18,000e
West Germany	na	na	na	na
Greece	441,252	385,067	478,335	509,095
Israel	6,952	6,900	6,287	6,000e
Italy	292,428	224,208	282,446	322,888
Spain	102,328	108,318	120,678	97,705
Turkey	4,357	8,280	7,937	15,000
Eastern Europe				
Bulgaria	274,700	179,700	205,700e	na
Hungary	80,000	82,000	72,488	78,000
Poland	76,730	89,820	161,587	157,090
Romania	63,000e	65,000e	65,000e	65,000e
USSR	na	na	na	na
Yugoslavia	116,000	154,000	na	na
Africa				
Algeria	24,337	35,664	36,000e	36,000e
Egypt	3,811	3,488	5,085	5,200
Morocco	4,807	4,800	1,015	3,284
Mozambique	2,744	3,000	1,656	1,500e
South Africa	37,221	34,519	46,394	51,815
Tanzania	35	20	80e	80e
Asia				
Burma	1,349	1,590e	1,500e	1,350e
China	na	na	na	na
India	150,568	153,026	146,922	158,675
Iran	25,000e	40,000e	20,000e	20,000e
Japan	400,000e	400,000e	400,000e	400,000e
Pakistan	1,089	1,113	1,265	1,347
Philippines	2,279	1,569	3,123	5,053
Oceania				
Australia	5,603	8,565	8,972	9,200e
New Zealand	2,633	9,824	4,954	3,000
World Total	5,865,347	6,529,465	6,697,648	6,426,598

e – Estimate na – not available

Source Institute of Geological Sciences, London and U.S. Bureau of Mines, Washington

Bentonite — a clarification

It is unfortunate that bentonite is somewhat obscured by the lack of mineralogical significance amongst the profusion of commercial and regional terms. This problem of nomenclature warrants some elaboration, if only to clarify the following discussion.

Much confusion has arisen over the different usages of the term 'fuller's earth' on opposite sides of the Atlantic. However, in both cases the term has a historical significance, and in view of modern absorbent markets, still bears a certain logic. Historically, the term referred to any clay which had the ability to absorb oil, grease, or colouring matter, which could be used for the cleansing or "fulling" of woollen cloth. A number of clays have this property, and accordingly have become known as fuller's earth. In the UK, calcium montmorillonite has been worked since Roman times, and hence has come to occupy the term to the exclusion of other absorbent clays. In the USA, the substitution of domestic attapulgite for imported English calcium montmorillonite led to the use of the term for this clay mineral group, although it is still used locally to describe montmorillonites, and mixed montmorillonites-sepiolites-attapulgites which ultimately find use as absorbent clays.

The bentonite industry is further complicated by a number of terms that may either express important characteristics of the clay (swelling bentonite, non-swelling bentonite, etc.) or the region where such a clay is produced (Wyoming bentonite, Texas bentonite, etc.). The term "bentonite" is a regional term itself, having been derived from the Benton shale at Rock River, in which the first bentonite mine in 1897 was thought to occur. In turn, the Benton shale drew its name from Fort Benton in Montana, 400 miles to the north of Rock River. For ease of reference, the common nomenclature of the group is set out in the accompanying table. Whilst deposits of calcium montmorillonite are relatively widespread, the other members of the smectite group of minerals are rare, and commercial exploitation is restricted by virtue of their limited occurrence. However, it was the Grand Crus deposits of natural sodium bentonite — virtually restricted to the Northwest USA — that led to development of the bentonite market. Speciality markets have been developed for the extremely rare lithium-magnesium smectite, **hectorite**; and an equally restricted magnesium smectite, **saponite**, has recently been launched onto drilling mud markets. Saponite has physical properties similar to bentonite, but is shear thinning, and has an extremely high yield point. The high magnesium content results in a very low ion exchange capacity, a better tolerance of electrolytes and a higher thermal stability.

Principal nomenclature of bentonite

Principal mineral	*Synonymous terms*	*Regional terms*
Smectite group (layered structure)		
Sodium montmorillonite	Synthetic bentonite Sodium bentonite Swelling bentonite Sodium-activated bentonite Sodium-exchanged bentonite	Wyoming bentonite (US) Western bentonite (US) Bentonite (UK)
Calcium montmorillonite	Calcium bentonite Sub-bentonite Non-swelling bentonite	Southern bentonite (US) Texas bentonite (US) Fuller's earth* (UK)
Hormite group (fibrous or chain structure)		
Attapulgite	Palygorskite Mountain wool, leather, etc.	Fuller's earth (US)
Sepiolite	Mountain wool, leather, etc. Meerschaum (in large lump form	Fuller's earth (US)

North America — predominant

Each of the principal North American countries is engaged in the production of bentonite although output from Canada and Mexico is dwarfed by that of the USA which alone accounted for some 60% of total world production in 1980 excluding the published figures for fuller's earth.

Official figures for bentonite production in Canada are not available owing to the small number of operators exploiting the mineral. Although *Dresser Minerals* works a deposit near Rosalind in Alberta only about 4% of output is used in the oil well drilling application. The main uses are in the fields of civil engineering, foundries, animal feed, and iron ore pelletisation. Through its subsidiary, *Pembina Mountain Clays*, *Filtrol Corporation* (now part of Kaiser Aluminium and Chemical Corporation) produces a calcium bentonite near Morden in Manitoba, the bulk of which is taken to the company's plant at Winnipeg for processing and chemical treatment. The newest bentonite producer to emerge in Canada is *Noranda Mines Ltd.* with its 34.5% stake in *Avonlea Mineral Industries* which it acquired in June 1981 with an option to increase its ownership to 51% at a later date. Avonlea is the only Canadian operation which mines a naturally occurring sodium bentonite at its 60,000 tpa operation near Wilcox in Saskatchewan. About 40% of output is used for oil well drilling and 20% for reservoir sealant material with the balance for animal feed, foundries, iron ore pelletisation, etc.

Bentonite production in Mexico has risen steadily in recent years to more than 176,000 tonnes in 1980 with a further 52,360 tonnes recorded for calcium bentonite in the same year. Mexico's principal producer, *Quimica Sumex SA de CV*, is a Mexicanised subsidiary of West Germany's *Süd-Chemie AG* and is engaged in calcium bentonite quarrying in several locations of which the largest are in the states of Tlaxcala and Morelos. Smaller operations in Durango, Zacatecas, and Michoacan provide Sumex with some 140,000 tpa of capacity. Processing is carried out at the company's plant at Puebla where surface treated clays are produced for bleaching, absorbents, filtration, etc. An affiliated company, *Tonsil Mexicana SA de CV*, also operates a plant in Puebla. Mexico's other major bentonite producer, *Arcillas Industriales de Durango SA de CV* has a quarrying capacity of 180,000 tpa at Cuencamé in Durango and is able to produce up to 140,000 tpa of processed material at its plant in Gómez Palacio, Durango. During 1980 the company extracted about 120,000 tonnes of raw clay at Cuencamé. A smaller scale plant is operated by *Tecnica Mineral SA* in Tlaquepaque, Jalisco where 3,000 tpa of bentonite capacity is available based on raw material from various locations in Zacatecas, Jalisco, and Michoacan states. The company has recently installed an acid activation plant as part of an expansion programme.

Production of 2,650 tonnes of bentonite is recorded in Guatamala although little is known about the country's bentonite operations.

USA — the world standard

After climbing through the 4m. tonnes mark in 1978 production of bentonite in the USA slipped gradually back to below 3.8m. tonnes in 1980 although production of calcium bentonite (montmorillonite) remained remarkably consistent through these years at around 553,000 tonnes. Preliminary figures for 1981 reveal that bentonite production has recovered somewhat, by almost 12%, to just under 4.25m. tonnes whilst the overall figure for fuller's earth (calcium bentonite and attapulgite) shows a 6% improvement from the 1980 figure of 1,392,000 tonnes to 1,475,000 tonnes.

The US natural sodium bentonite industry is dominated by about eight major corporations some of which have overseas extensions to their business. *American Colloid Company* is heavily involved in the production of both sodium and calcium bentonite although its natural sodium bentonite operations far outweigh the fuller's earth operation. At its four plants in Wyoming, South Dakota, and Montana, American Colloid has the capacity to produce up to 1.4m. tpa of sodium bentonite. This compares with a production capacity of around 300,000 tpa of calcium bentonite at the two plants in Alabama and Mississippi. In addition the company has a further 220,000 tpa processing capacity at other US locations in Maryland, Ohio, Illinois, Wisconsin, and Indiana. The overseas dimension for American Colloid consists of subsidiary company's with processing plants in Wallasey, UK *(Volclay Ltd.)*; Duisbury, West Germany *(Bentonit International GmbH)*; Erandio Bilbao, Spain *(Volclay Espana SA)*; Geelong, Australia *(Volclay Standard (Pty) Ltd.)*; and Hamilton, Canada *(Volclay Canada Ltd.)*. Taken together these overseas operations have around 180,000 tpa processing capacity.

Wyo-Ben Inc. is solely concerned with the production of natural sodium bentonite in Wyoming at three locations which have a combined capacity of 1,165,000 tpa although the company's recently built $4.5m. Thermopolis plant is readily able to double its capacity to 600,000 tpa if necessary. Initial production at Thermopolis began in January 1981. Expanded capacity is, however, unlikely in the short term owing to current output being only around 50% of current capacity. *Federal Bentonite Division, Aurora Industries Inc.* presently operates in two major locations, Colony and Upton, Wyoming where combined production capacity is around 450,000 tpa of sodium bentonite. A variety of grades are produced in granular and ground forms mainly for iron ore pelletisation with over 60% of sales and most of the balance split between foundries and oil well drilling. The 300,000 tpa mine and plant at Glasgow, Montana still awaits commissioning. A semi-finished product which is crushed and dried at Burnett, Minnesota is supplied to the taconite iron ore markets in Michigan and Minnesota. *International Minerals and Chemical Corporation* operates a mine and plant at Colony, Crook County, Wyoming for the production of sodium bentonite for oil well drilling, foundries, and water retention applications. IMC's other operation is concerned with the production of calcium bentonite at Aber-

deen, Mississippi for foundries, animal feed, etc. *Kaycee Bentonite Corporation* has a combined production capacity of 450,00 tpa of sodium bentonite from its two plants at Casper and Worland, Wyoming, mainly for iron ore pelletisation, oil well drilling, animal feed, etc. Although the Colony mine is the only one in operation the *Baroid Division of NL Industries* owns reserves of sodium bentonite in Montana, South Dakota, and Wyoming. Capacity of around 900,000 tpa at Colony provides the company with material for oil well drilling fluids for use within the company as well as for outside marketing to other end uses. The principal US operation of *Dresser Minerals* is at Greybull, Wyoming where up to 650,000 tpa of raw clay feeds the company's 430,000 tpa beneficiation plant. Slightly more than half of Dresser's output is used for in-house production of drilling fluids with the balance used for iron ore pelletisation. The smallest of the natural sodium bentonite producers is the *Georgia Kaolin* subsidiary, *Benton Clay Company*, with its 120,000 tpa operation in Casper, Wyoming where granular and pulverised grades are produced for foundries, drilling, and pelletising applications are produced.

Southern bentonite . . .

Production of so-called southern bentonite is dominated by two major corporations — *Oil Dri Corp. of America* and *Lowe's Inc.* — and several smaller capacity operations spread through the states of Mississippi, Georgia, Missouri, Tennessee, Texas, Nevada, and California. Oil Dri operates two mines and associated plants at Ripley, Mississippi and Ochlocknee, Georgia with a combined capacity in excess of 250,000 tpa. The Georgia operation is based upon a 20/80 attapulgite calcium bentonite mixture. A variety of grades are produced for industrial oil and grease absorbents, cat litter, and carriers for agricultural chemicals. Marketing of the company's products is undertaken by its European subsidiary, *Oil Dri SA*, based in Switzerland with distribution outlets at Immingham, UK and Cologne, West Germany. Lowe's Inc. has five operations in Tennessee, Missouri, Illinois, and California with a combined operating capacity in excess of 500,000 tpa for the production of industrial oil absorbents, cat litter, and agricultural chemical carriers. *Anschutz Minerals Corp.* operates a mine and plant at Ochlocknee, Georgia where up to 270,000 tpa of raw clay consisting of a mixed layer of calcium montmorillonite, diatomite, kaolin, and attapulgite is processed for cat litter and oil absorbent products. Up to 90,000 tpa of refined products are produced. Other companies worthy of mention in this area are *BASF Wyandotte Corp.* with operations in Tippah County, near Blue Mountain, Mississippi and *Filtrol Corp.* near Smithville and Raleigh, Mississippi.

In Texas, *Southern Clay Products Inc.*, a subsidiary of *Anglo American Clays* mines calcium bentonite at its Gonzales 27,000 tpa operation it acquired from *Georgia Kaolin Co.* in 1979. Currently the plant is undergoing extensive renovation to increase efficiency and capacity. A number of grades are produced including organically modified bentonites used in oil well drilling, paints, inks, adhesives and greases; highly refined white bentonites for use in personal care preparations — cosmetics and pharmaceutical products — and ceramics; and industrial grades for foundries, civil engineering, drilling muds, etc. Other producers in Texas include the *Millwhite Company* at Flatonia and Riverside and *Balcones Minerals* near Flatonia.

. . . and in the west

In the western USA there are a number of producers of calcium bentonite amongst which the most important is *Wilbur-Ellis* with its mine in central California, some 70 miles west of Fresno where the company has one processing plant and another at Florin, near Sacremento. Production capacity is in the 35/50,000 tpa range for pelletising, cubing, animal feed, and civil engineering markets. The company's product is described as a low swelling California bentonite which consists of

Fuller's earth sold or used by producers in the USA
('000s tonnes)

State	*1977*	*1978*	*1979*	*1980*
Florida				
Attapulgite	394	412	446	378
Montmorillonite	—	—	—	—
Total	394	412	446	378
Georgia				
Attapulgite	316	397	393	386
Montmorillonite	162	165	172	203
Total	523	562	565	589
Nevada & Utah				
Attapulgite	na	na	na	na
Montmorillonite	na	na	na	na
Total	na	na	na	na
Other states				
Attapulgite	25	26	33	76
Montomorillonite	355	388	381	348
Total	380	414	414	424
Total Fuller's Earth				
Attapulgite	779	834	870	840
Montmorillonite	517	554	553	552
Grand Total	1,296	1,388	1,423	1,392

equal proportions of sodium and calcium varieties. *Industrial Mineral Ventures* has recently started production of a complex mixed clay comprising calcium bentonite, saponite, sepiolite, and hectorite at its mine at Imvite, Bye County, Nevada where up to 60,000 tpa of raw clay may be produced. The company's plant at Lathrop Wells, Nevada has 90,000 tpa capacity for drilling, filler, sealant, and suspension clay markets. *R.T. Vanderbilt Co. Inc* has a calcium bentonite operation at Beatty, Nevada with processing capacity in California and Nevada for the production of cosmetic, pharmaceutical, and speciality chemical grades.

World production of Fuller's earth* *(tonnes)*

Country	*1977*	*1978*	*1979*	*1980*
Algeria	4,263	4,847	5,000e	5,000e
Argentina	4,129	3,482	5,445	7,408
Australia	50	68	50e	50e
India	13,517	16,297	17,343	30,985
Italy	23,424	10,195	1,080	4,300
Mexico	61,369	40,615	48,820	51,360
Morocco	21,025	29,880	13,586	17,430
Pakistan	18,000e	16,000e	42,822	24,463
South Africa	—	258	919	720
UK	159,000e	167,000e	171,000e	163,000e
USA	1,296,122	1,387,647	1,422,690	1,391,443
World Total	1,600,899	1,676,237	1,728,755	1,696,159

**The figure for the USA refers to clay used for bleaching or absorbent applications and comprises mainly attapulgite and calcium montmorillonite. Fuller's earth is also known to be produced in France, West Germany, Iran, Japan, Turkey etc. for which figures are not readily available*
e — Estimate
Source Institute of Geological Sciences, London and U.S. Bureau of Mines, Washington

South America

Argentina and Brazil are the major producing countries in the South American continent with steadily increasing output at the end of the 1970s to 1980 when Argentina reached almost 175,000 tonnes and Brazil almost 250,000 tonnes. Additionally Argentina records 7,400 tonnes of Fuller's earth for 1980, output which has also gradually increased during the same period from just over 4,000 tonnes in 1977. Peru has consistently produced around 40,000 tpa of bentonite in recent years and Colombia has a very small production recorded at something just over 1,000 tpa.

Two companies are of importance in Argentina — *Geberovich Hnos. SCC* with its 60,000 tpa operation at Zapala, Neuquén Province and *Industrias Petral Srl* with several mines in the region of Calingasta and 30,000 tpa plant at Chimbas, San Juan. In Brazil *Bentonit Uniao Nordeste SA* operates a 180,000 tpa bentonite mine at Campina Grande in the district of Boa Vista, Paraiba State which feeds a plant with a nominal capacity of 192,000 tpa of sodium and calcium bentonite products. In mid 1976 *Laporte Industries* of the UK acquired a 40% interest in the Bentonit Uniao Nordeste operation. In Peru *Minera Buribent SA* has large deposits of bentonite in Piura, some 1,000 kms north of Lima, and others to the south of the city. In the region of 10,000 tpa of sodium bentonite is produced by the company at its Lima plant mainly for oil well drilling, foundries, pelletisation, and animal feed. In Callao the company has been constructing an acid activation plant at a cost of $2.5m. for the production of 20,000 tpa for fish, vegetable, and mineral oil discolouring applications. The other Peruvian bentonite producer is *Cia Minera Agregados Calcareous SA* which extracts calcium bentonite at Ica in southern Peru and sodium bentonite in Piura State in the north. The company's plant in Lima has a production capacity of 400,000 tpa although this represents total capacity for the company's extremely diversified mineral output. Bentonite capacity is in the order of 3,000 tpa for foundries, animal feed, pelletisation, etc.

Western Europe

Five countries in western Europe regularly produce in excess of 100,000 tpa of bentonite of the calcium montmorillonite variety — West Germany and the UK in the north and Greece, Italy, and Spain in the Mediterranean region. Smaller production is recorded in France, Cyprus, Israel, and Turkey which taken together probably produced no more than around 65,

70,000 tonnes in 1980. In contrast production in the big five producing countries during 1980 probably exceeded 1.5m. tonnes including estimated output from West Germany at around 500,000 tonnes.

Northern Europe — Süd-Chemie dominates

Owing to the dominating position of *Süd-Chemie AG* in West Germany bentonite production figures for the country are not available although it is believed that the company has some 700,000 tpa production capacity at its plant in Moosburg near Munich which processes calcium bentonite from various locations in Bavaria to produce sodium exchanged bentonite and acid activated material. Sales of the sodium bentonite are directed towards the West Germany foundry industry, the single most important sector, civil engineering applications, and agricultural products. Süd-Chemie, through subsidiary companies, also possesses bentonite in other locations — Puebla in Mexico through *Quimica Sumex*; Le Treport in France through *Sté Française des Bentonites et Dérivés SARL* which operates closely with Süd-Chemie's Giba operation in Sardinia — *Süd-Chemie Italia SpA*. The Le Treport processing plant underwent expansion during 1981 and began operating earlier this year with the new capacity. West Germany's only other bentonite producer is *Erbsloh & Co.* form its mines and plants in Landshut where the company is able to produce up to 100,000 tpa of activated and unactivated bentonite products for foundries, drilling, civil engineering, animal feed, etc.

Laporte renovates in the UK

The UK constitutes northern Europe's only other major producer of bentonite with production capacity approaching 300,000 tpa although output in 1980 was estimated at only around 163,000 tonnes of fuller's earth, down from the peak 1979 figure of 171,000 tonnes. As these figures, published by the Institute of Geological Sciences, are based on estimates of saleable production they can only be used as a guide. Most of UK fuller's earth production is sodium exchanged but a smaller proportion is acid activated and some is sold in the untreated form as fuller's earth. The largest of the UK producers is *Laporte Industries Ltd.* which operates a number of quarries in the Redhill district of Surrey in southern England and owns further reserves, currently not worked, at Bath, Avon; Maidstone, Kent; and Clophill, Bedfordshire. The company's plant at Redhill is nearing completion of a £4m. renovation programme which will provide the company with greater efficiency and production capacity of around 190,000 tpa. In early 1981 Laporte opened a new £5m. acid activiation plant at Widnes, Merseyside to replace the older facility at Redhill. Raw material from Redhill feeds the new 30/35,000 tpa Widnes plant which manufactures the company's 'Fulmont' and 'Fulcat' product range half of which is earmarked for export. Overall Laporte's principal markets are foundries, pet litter, and bleaching applications with smaller volumes for oil well drilling, civil engineering, agriculture, animal feed, and industrial absorbents. *Steetley Minerals Ltd.* has a quarry and plant near Woburn, Bedfordshire with a capacity of up to 50,000 tpa of sodium exchanged bentonite. In addition the company operates a plant at Middlesbrough which processes imported clays from the USA and Mediterranean areas thus providing considerable flexibility in satisfying the market with a variety of bentonite blends. A significant amount of Steetley's material is exported especially to foundries and iron ore pelletising plants in Scandinavia. The UK's third bentonite producer is *Brett Bentonite Ltd.*, a subsidiary of *Robert Brett & Sons Ltd.*, with its 50,000 tpa planf based on a quarry near Baulking in Oxfordshire. Since commissioning the plant in 1979 Brett has been developing markets in the foundries, civil engineering, and oil well drilling sectors.

Ceca in France . . . and elsewhere

France is the only other country in northern Europe with any sizeable bentonite production which was around 18,000 tonnes in 1980 compared with 16,069 tonnes in 1979. The principal company involved is *Ceca SA* with its mine and plant at Bergerac However, the company is also involved in bentonite production in other parts of Europe — Greece, Sardinia, and Spain – and has a total production of around 90,000 tpa. Most of the company's output is sodium exchanged for foundry applications and oil well drilling.

The Mediterranean — Milos sets the pace

Bentonite production in Greece has gradually risen during the 1970s to 509,095 tonnes in 1980 based on the extensive deposits on the island of Milos where three companies account for most of the production. *Silver and Baryte Ores Mining Co.* is the largest of the island operators with 350,000 tpa of raw clay production capacity backed by 400,000 tpa of sodium bentonite processing capacity at the company's plant at Voulthia Bay. S&B's bentonite business has grown from demand for iron ore pelletisation grades in Canada's steel industry. *Mykobar Mining Co. SA*, a subsidiary of *Dresser Industries Inc.*, is the second major producer on Milos with 120,000 tpa capacity for raw clay production and 60,000 tpa of sodium bentonite at its main plant in Adamas Bay. A second plant at Aghia Anna produces a further 5,000 tpa of sodium bentonite. Most of the company's output is sold on world markets for foundry applications and about 25% of output is used for oil well drilling fluids required by the company's own drilling mud business. The *Mediterranean Bentonite Co. Ltd.*, a subsidiary of Italy's Industria *Chimica Carlo Laviosa della Carlo Laviosa SpA* mines up to 300,000 tpa of raw clay for shipment through the port of Adamas on Milos Island to the company's Livorno plant in Italy for processing.

Carlo Laviosa ahead in Sardinia

Bentonite production in Italy increased to 322,888 tonnes in 1980 but during 1981 this fell back by 14% to 277,349 tonnes. Italian production of fuller's earth has fallen from 23,424 tonnes in 1977 to around 4,300 tonnes in 1980 although production fell to just over 1,000 tonnes in 1979. As with Greece the bulk of Italy's bentonite production comes from an island — Sardinia — where the deposits occur on the western side in a north to south trending belt. *Industria Chimica Carlo Laviosa della Carlo Laviosa SpA* mines bentonite at Pedra de Fogu and Puntenuovo with processing carried out at Villaspeciosa, Cagliari and Santa Giusta, Oristano. The Cagliari plant produces up to 40,000 tpa whilst the Oristano plant is able to process up to 165,000 tpa of sodium bentonite. Sardinian operations for the company are run by a Laviosa subsidiary, *Mineraria Chimica Sarda SpA* established in 1972. Most of the processed Sardinian material leaves the island in semi-finished form to be further processed at the company's mainland 142,000 tpa plant at Livorno which also draws on raw clay supplies from Laviosa's Greek operation on Milos Island. Most of the material from Livorno is consumed in Italy in foundries, drilling muds, civil engineering, and special grades for cosmetics, pharmaceuticals, and wine clarification. *Baroid International SpA* derives its material from deposits in Nurallao in south central Sardinia and Giba in the southwest. Processing is carried out at the company's 40,000 tpa plant at Sant' Antioco where the clay is sodium exchanged principally for drilling mud applications in North Africa and the Persian Gulf. *Süd-Chemie Italia* operates a 110,000 tpa plant near Giba for foundry and pelletising applications. In the Trexenta district at the village of Mandas *Edi sarda SpA* quarries bentonite for processing at its Cagliari plant for the production of drilling mud quality destined for North African and Middle East drilling mud markets. In the north of Sardinia *Caffaro SpA* extracts the bulk of its raw material although some bentonite comes from an underground operation at Mondaino, Pesaro. All of the company's output is shipped to its acid activation plant at Porto Marghera near Venice where up to 24,000 tpa of bleaching earths are produced to be marketed under the 'Prolit' trade name. Other companies operating in Sardinia include *Ceca Italiana* with 50,000 tpa of raw clay capacity and *Sardamin* with its mine and plant at Torralba able to produce 20,000 tpa of sodium bentonite. By the beginning of 1984 Sardamin hopes to increase capacity to 35/40,000 tpa. On the Italian mainland *Elba SpA* mines and processes up to 15,000 tpa of bentonite at Arsiero although not all the clay is sodium exchanged. *Ditta Dott Settimio Cinicola Industria Mineraria* operates several quarries in the Foggia and Campobasso districts for processing at the company's 50,000 tpa plant in Castelnuovo della Daunia, Foggia. Grades of both sodium and calcium bentonite are produced. *Valdol SpA* operates three mines and two plants providing the company with a total of 80,000 tpa of raw clay and 75,000 tpa of sodium bentonite capacity. One mine and plant is operated at Maglio di Sopra, Vicenza where up to 50,000 tpa of sodium bentonite is produced. Two other mines are worked at Recoraro and S. Giovanni each with 10,000 tpa of raw clay capacity and a 25,000 tpa plant is worked at Altavilla Vicentina. Foundry and oil well drilling markets consume most of Valdol's production. Finally *Stà Mineraria Estrattiva Srl* operates a 25,000 tpa sodium bentonite operation at Pietracuta de S. Leo, Pesaro.

Minas de Gador in Spain

Output of bentonite in Spain reached a peak of 120,678 tonnes in 1979 but this dropped sharply by almost 20% to 97,705 tonnes in 1980. The main producing region is Almería with 50,197 tonnes produced in 1980 followed by Toledo where 37,568 tonnes was produced. The Province of Madrid accounts for the balance of 1980 production with 9,940 tonnes. Spain's most important producers is *Minas de Gador SA* which is 40%

owned by *Laporte Industries* of the UK. Bentonite is produced from a large mixed deposit containing calcium/sodium/magnesium montmorillonite and a calcium-based absorbent clay at Serrata de Nijar in Almería. From this material the company produces up to 90,000 tpa of sodium bentonite and 12,000 tpa of acid activated clay for bleaching applications. Up to around 12,000 tpa of absorbent granules are produced for pet litter applications. The company's 12,000 tpa operation at Yuncas, midway between Madrid and Toledo, is based on bentonite and sepiolite deposits mined at Pinto, Valdemoro, and Parla in Madrid Province. Here the bentonite is sodium exchanged and ground for drilling, foundry, and absorbent applications whilst the sepiolite is also processed for drilling applications. *Tolsa SA*, Spain's major producer of sepiolite is pulling out of the production of bentonite for which it had a small operating capacity at Yunclillos, Toledo. *Minera Arregui SA* operates a 36,000 tpa raw clay operation at Castellon, Malaga and *Ceca Espaniola SA* has a small bentonite operation in Almería alongside its attapulgite and sepiolite facility.

Peletico to expand on Cyprus

Estimated production for Cyprus has shown significant increases for bentonite production through the turn of the decade with 7,000 tonnes for 1979, 23,000 tonnes for 1980, and 45,000 tonnes for 1981. Although Cyprus has produced bentonite on an intermittent basis for many years the emergence of several companies has led to more positive development of the island's bentonite resources. In particular *Peletico Ltd.*, which began operations in 1975, has built up its activities based on several deposits in the area around Pentakomo village some 15 miles from Limassol towards Nicosia. Here the bentonite is excavated and sodium exchanged using the extrusion process, dried, and transported 32 miles to the company's Aradippou plant, five miles from Larnaca for further processing and grinding to supply oil well drilling markets under the trade name 'Bentocyp'. The Pentakomo sodium exchange plant has 60,000 tpa capacity whilst the grinding plant at Larnaca has the ability to produce 30,000 tpa. The material is sold in bags or in granular form for local grinding in the overseas market. Granular material is shipped in bulk from Vassiliko Bay, some five miles from the mining operation. Ground and bagged material is shipped from the port at Larnaca. The company is now embarking on marketing its products to the civil engineering industry, as well as for animal feed and pesticides. An investment programme for 1983/84 amounting to $2m. will increase the company's output to 100,000 tpa. *Drapia Mining Co. Ltd.* has a 30,000 tpa sodium bentonite operation near Drapia in the Kalavasos area of the country where raw clay is produced for animal feed. Drapia holds an estimated 6m. tons of reserves near Drapia and is presently investigating the potential for setting up a plant to process the raw clay for applications in drilling, foundries, pelletisation, and bleaching, etc. Other small bentonite producers on Cyprus include *Demi Mitides* which produces a ground 100 mesh product.

In and out in Turkey

Turkish production of bentonite has also risen sharply in recent years from 4,357 tonnes in 1977 to 30,687 tonnes in 1981. Several companies are engaged in bentonite production in the country although the first and largest in the business, *Sanayi Madenleri AS (Samas)*, is understood to have stopped production for the time being owing to financial difficulties. Samas mining operations are concentrated around Reşidaye about 450 km from Ankara. Capacity of the company's plant at Reşidaye is about 60,000 tpa although output has apparently only reached about 20,000 tpa in the past mainly for domestic markets. Essentially Samas' bentonite varies in composition between the natural sodium and natural calcium varieties. *Emko Bentonit Ticaret ve Sanayi AS* now constitutes Turkey's largest bentonite producer with around 30,000 tpa of raw clay production capacity based on sodium/calcium bentonite quarries at Çankiri and processing plant at Esenboğa just to the north of

Ankara. Most of Emko's output is consumed in the domestic foundry and oil well drilling industries. A more recent development in Turkey concerns *Turan Madencilik Sanayi ve Ticaret Ltd.* which produces smaller volumes, up to 500 tonnes per month, of white high quality bentonite near the village of Kertil between the Bigadiç and Kepsut counties of Balikesir. Here the clay consists of 98% montmorillonite in three superimposed layers, each about six metres in thickness. Production of acid activated and soda ash treated clays has recently been started by Turan although present production capacity is small and supplies domestic markets although exports may be on the horizon. However, a new 120 tonne per day plant is under construction near the port of Bandirma on the Marmara Sea. Turan Madencilik is part of the *Dolsan-Mavaş Group* and since its inception some two years ago has been processing its raw clay at Dolsan's plant in Eskişehir. Other producers in Turkey include *Basik Ateş Tugla Sanayii ve Ticaret Ltd.* which has 10,000 tpa of raw clay production capacity at its mine at Arnavutkoy near Istanbul and *Kale Medencilik & Kale Muhendislik* with its operation at Tokat. These companies produce small volumes for domestic use mainly in foundries.

Australasia — Cudgen expanding

Recorded statistics for bentonite production in both Australia and New Zealand are quite small at around 9,200 tonnes and 3,000 tonnes respectively for 1980. Australian output has maintained about this level of output for the period 1978-1980 whilst New Zealand's production has dropped from almost 10,000 tonnes in 1978.

Two companies are presently engaged in the production of bentonite in Australia — *Cudgen R.Z. Ltd* and *Steetley Industries Ltd.* Cudgen mines bentonite in two locations at Gurulmundi and Woleebee near Miles in southwest Queensland. Both deposits are of the naturally occurring sodium bentonite variety. Whilst some milling takes plce at Gurulmundi for the production of animal feed grades most of the grinding is done at the company's plant in Brisbane where a new Raymond mill is presently being installed. Present output is now running at about 30,000 tpa although the new milling installation can be rapidly expanded to 50,000 tpa. Specifications conform to the normal international standards and the API requirement in particular. Since starting operations in 1978 Cudgen has been able to double its sales each year with projected 1982 sales representing a 30% increase on the figure for 1981. Of particular interest the company is presently testing a special drilling grade of bentonite for use in high temperature applications such as geothermal wells. Steetley mines bentonite at Wingen in New South Wales and carries out processing at Newcastle. Here the raw material comprises eight horizons of calcium bentonite in Upper Permian sediments. At present production is around 6,000 tpa mainly for foundry and civil engineering applications.

New Zealand's principal bentonite producer is *Canterbury Bentonite Ltd.*, a subsidiary of *TNL Group Ltd.*, which has a mine and plant at Coalgate, Canterbury Plains some 65 miles from Christchurch and 75 miles from the port of Lyttleton. Some 30,000 tpa of granular sodium bentonite and 8,000 tpa of ground sodium bentonite is produced under the 'Rheogel' trade name for drilling muds (45%), civil engineering (25%), foundries (25%), etc. Untreated calcium bentonite in granular form or ground to 200 mesh is sold under the trade name 'Calben'. Sales of bentonite are handled by *Mintech (N.Z.) Ltd.*, the marketing arm for TNL. *New Zealand Bentonite Ltd.* is a smaller company operating at Porangahau, Hawkes Bay.

Africa — enter Cape Bentonite

The major producing country on the African continent is South Africa followed by Algeria and much smaller volumes in Egypt, Morocco, Mozambique, Namibia, and Tanzania.

South African production reached 51,815 tonnes in 1980 but declined to 44,372 tonnes in 1981 and the first six months of 1982 indicate a further decline for the full year with a half year figure of just 15,543 tonnes. The calcium bentonite deposits near Parys in the Orange Free State are worked by *G & W Base and Industrial Minerals (Pty) Ltd.*, a subsidiary of Anglo's *Zimro (Pty) Ltd.* Milling operations are carried out in Cape Town and sodium exchange takes place at the company's Wadeville plant at Germiston near Johannesburg. Around 40,000 tpa of sodium bentonite is able to be produced, most of which is marketed to the domestic foundry industry although some is used for pelletising, dam sealing, drilling, and industrial water treatment. In early 1980 *Cape Bentonite (Pty) Ltd.* began operations based on a deposit near Heidelburg some 300 kms from Cape Town. Around 4m. tons of bentonite has been proved in a number of horizons some of which contain pure sodium magnesium bentonite requiring no sodium exchange whilst others require a maximum addition of 1% soda ash in order to meet the API drilling mud specifications. A horizon of white bentonite requires addition of 2% soda ash to develop optimum properties. Currently 15,000 tpa can be milled and supplied from the Heidelburg plant although this capacity can be easily increased to 50,000 tpa. In addition the company has an extra 30,000 tpa capacity at its Germiston plant. Officially marketing is handled by the company's majority shareholder — *Metallgesellschaft* of West Germany. *Rondebult Clayworks* of Boksburg, a subsidiary of *Mineralchem Ltd.*, mines bentonite in the Koppies District of the Orange Free State and at Rondebult in the Transvaal. Processing capacity of 10,000 tpa exists at the company's plant at Boksburg for foundry applications mainly. Small bentonite production is performed by *Pretley Perlite Mining Co. (Pty) Ltd.* in Zululand.

Algeria produces around 36,000 tpa of bentonite and 5,000 tpa of fuller's earth most of which is produced by *Société Nationale de Recherches et d'Exploitations Minières* (SONAREM) from deposits at Mostaganem and Marina. In Mozambique around 1,500 tons was produced in 1980. The country's main operator is *Luzinada Umbeluzi Mina Lda.* The *Tanganyika Meerschaum Corp. Ltd.*, now part of the *Tanzania*

State Mining Corporation produces bentonite at Sinya some 100 miles from Arusha in northern Tanzania. The deposit consists of magnesium-rich clays and dolomite and occurs in long belts of about three to four metres in thickness. Capacity is difficult to assess as this depends upon demand from the drilling industry, foundries, and civil engineering applications. Most of the material is consumed domestically although negotiations are underway with United Arab Emirate, Saudi Arabia, Bahrain, and Indonesia.

The Far East

India and Japan are the most important bentonite producers in the Far East with smaller output recorded in the Philippines, Burma, and Pakistan.

India — Gujurat State dominates

Production in India for 1980 amounted to 158,675 tonnes which represents an 8% improvement over the slightly depressed figure of 146,922 tonnes produced in 1979. Major bentonite deposits are found in the states of Bihar, Gujurat, Jammu, Kashmir, Rajasthan, and Tamil Nadu whilst further resources have been found in more recent years in Assam, Madhya Pradesh and Uttar Pradesh. So far as fuller's earth is concerned the most significant deposits occur in Andhra Pradesh, Assam, Gujurat, Madhya Pradesh, Rajasthan, Karnataka, and Tamil Nadu. Commercial production of bentonite in India is dominated by six major companies although smaller output is produced by a number of small scale concerns. The states of Gujurat and Rajasthan are the principal centres of production. The largest producer is *Ashapura Minechem Pvt. Ltd.* with its quarries and plants located in Kutch and Bhavnagar districts of western India. Ashapura intends to produce 86,000 tonnes this year in line to meet its target of 100,000 tonnes by the end of 1983. The company mines selectively for blending purposes in order to meet specifications for the OCMA/API standard for oil well drilling, as well as markets for foundries, pelletisation, civil engineering, and animal feed. Ashapura exports material to other Far Eastern countries, the Middle East, Africa and is developing exports to Europe and Australia. By mid-1983 the company expects to begin production of 10/15,000 tpa of attapulgite and a similar amount of china clay. A one time associate of Ashapura but now under completely separate management, *Ambica Minechem Industries*, also produces bentonite from mines in Kutch and Bhavnagar Districts of Gujurat State to supply its two plants at Bhavnagar and Gandhidam. The company has a total of 40,000 tpa sodium bentonite capacity for oil well drilling, foundry, and other applications. *Kutch Minerals*, an associate of *Khimjee Hunsraj* which is one of the largest exporters of oil well drilling grade bentonite, also produces bentonite at Kutch with plants at Kutch-Mandvi and Gandhidam in Gujurat State. Combined processing capacity at Kutch is 30,000 tpa of bentonite although several other associated companies within the group produce more than 40,000 tpa of ground bentonite. Essentially Kutch Minerals produces four grades of bentonite — Indoclay for foundries, Indogel and Smectogel for oil well drilling, and Pharmagel for cosmetic and pharmaceutical applications. *Gimpex Minerals Pvt. Ltd.* has 60,000 tpa sodium bentonite capacity at its mine and plant at Bhuj, Gujurat State which produced mainly oil well drilling grades to capacity during 1980. Other significnt producers in Kutch includes *Messrs. Chatuubhuj Nranji* through its subsidiary, *Swastik Minerals*, with 25,000 tpa capacity, *Kasamuli & Sons Minerals Pvt. Ltd.* with its 20,000 tpa operation at Bhavnagar for sodium and calcium bentonite, *Gandhisons* with around 8,000 tpa capacity, and *Hargovindas Shivlal & Co.* with around 2,500 tpa output of sodium and calcium bentonite. A further significant company involved in Gujurat State is *Bombay Sewree Chemicals Manufacturing Co. Pvt. Ltd.* with operations at Sewree, Bombay and Vapi, Gujurat for the production of around 3,300 tpa of acid activated bentonite. The

Bombay plant is able to produce about 1,500 tpa whilst the two Vapi plants have capacities of 1,200 tpa and 600 tpa. Recent production has been running at around 2,150 tonnes. The company expects to uprate capacity at the Vapi plants during the next two years. In Rajasthan *Neelkanth Chemical Works* produces up to 25,000 tpa of sodium bentonite at its plants at Barmer and Jodhpur mainly for oil well drilling, foundries, and civil engineering. *Atul Mining Works* and *Rajasthan State Mineral Development Corporation* also have small bentonite production in Rajasthan at Bhawanimandi and Akli respectively.

Japan's unique industry

Estimated production of bentonite clays in Japan continues to be around 400,000 tpa although consumption, mainly domestic, reached 446,571 tonnes in 1979. Of significance in the consumption figure is the inclusion of about 40,000 tpa of bentonite imports from Wyoming, USA. Additionally some 73,000 tpa is consumed for the production of acid activated clay and around 8,000 tpa of acid clay is consumed.

The "Green Tuff" region is noted for many occurrences of montmorillonitic clays, most of which were formed by diagenesis and/or low-temperature hydrothermal alteration of acidic tuff and tuffaceous sediments in a marine environment (Takeshi, 1968). However, these clays are rather different in properties due to the interlayer cations and associated minerals. Montmorillonitic clays in Japan were divided into bentonite and acid clay. The former is characterised by the considerable swelling ability in water, and the latter by its acidity in water (Kato, 1968). In short, the former consists mainly of Na-montmorillonite and the latter of H-montmorillonite. Some acid clays are activated by warm sulphuric acid to achieve higher bleaching activity. The accompanying table shows the differences in composition and properties between bentonite (Na-bentonite) and acid clay (including raw material of activated earth).

Bentonite is mined at Usui area (Gunma Pref.), Aterazawa (Yamagata), Mikawa (Niigata), Kuroishi (Aomori), etc., in northeast Honshu, and Ohta (Shimane) and Kita-kyushu (Fukuoka) in western Japan. Excluding Kita-kyushu, all of the above deposits occur in the "Green Tuff" region comprising the Miocene volcanic sediments. Also, the main acid clay and activated earth producing areas are Nakajo (Niigata), Itoigawa (Niigata), and Muzusawa (Yamagata). They also occur in the same region with the bentonite.

Bentonite is mainly used for foundries, civil engineering, iron ore pelletising, and drilling mud applications. Foundry applications are the most important representing about one third of Japanese demand.

The utilisation of bentonite has steadily expanded in recent years. The development of organophilic bentonites is the most significant. Due to their excellent viscosity, swelling and gel-consistency particularly to low-polar solvents, these compounds are used as valuable submaterials of paint, printing ink, grease, cosmetics, etc.

Activated clays are mostly used for bleach of natural oils, fats, and petroleum. The considerable decrease of bleaching earth consumption by the petroleum industry in the past ten years is mainly due to the development of the hydrogeneration technology in oil-refining. Acid clay was also used as a bleaching earth at first, but now it is used only for insecticide carriers and fillers.

The principal companies engaged in bentonite production in Japan are *Kunimine Industries Co., Ltd.* and *Hojun Kogyo Co. Ltd.* which have nearly 400,000 tpa raw clay production capacity between them. Hojun Kogyo operates mines near

Tomoika-shi, Myogi-machi, and Annaka-shi for its processing plants at Annaka and Haraichi. Current output is around 132,000 tpa mainly for foundries (44%), civil engineering (25%), and insecticide carriers (13%), although the operating capacity is about 180,000 tpa. Kunimine Industries has mines at Tsukinumo, Yamagata and Kawasaki, Miyagi which are able to produce over 200,000 tpa of raw clay. The company's main plant is located at Aterazawa, Yamagata and has 150,000 tpa of sodium bentonite capacity. A second plant provides the company with 40,000 tpa of acid activation capacity and 12,000 tpa of calcium bentonite production, both mainly for foundry applications. *Kuroishi Bentonite Co. Ltd.* operates a mine and plant at Kuroishi, Aomori where up to 50,000 tpa of sodium bentonite may be produced. However, the company went into liquidation towards the end of 1981 and was subsequently taken over by *Nihon Kousan Co. Ltd.* and *Mitsui Mining and Smelting*. In the last full year of production the company produced some 18,000 tpa of bentonite but to November 1981 only 8,500 tonnes was produced. A smaller bentonite operation producing up to 1,500 tonnes per month is worked by *Nihon Bentonite Co. Ltd.* in Aomori Prefecture.

Mizusawa Industrial Chemicals Ltd. is Japan's most important producer of acid clys from its mines at Tsuruoka, Yamagata and Nakajo and Shibata, Niigata which have a combined capacity of 150,000 tpa. The company's plants at Tsuruoka and Nakajo have respective operating capacities of 15,000 tpa and 60,000 tpa. As part of the treatment process which involves acid activation of the clay the company produces a supermicronised silica used in the manufacture of carbonless copying papaer, gypsum, aluminium sulphate, and other chemicals as by-products. The principal product is activated bleaching earth sold under the trade name 'Galleon Earth' for the refining of petroleum and purification of fats and oils. *Nippon Activated White Clay Ltd.* and *Toyo Clay Ltd.* also produce acid clay in Japan although combined production capacity is less than half of Mizusawa's.

Chemical composition, cation exchange capacity, and some properties of bentonitic clays in Japan

(1) Chemical composition examples

Specimen	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	Na_2O	K_2O	*Ig. loss*		*Total*
(1) Bentonite (Yamagata)	75.01	0.10	12.75	1.41	—	1.00	1.04	2.63	1.04	4.72		99.70
										H_2O+	H_2O-	
(2) Bentonite (Gunma)	70.59	0.13	11.40	0.61	0.41	0.06	0.97	1.71	0.56	3.81	8.36	99.43
(3) Acid clay (Itogawa)	55.85	0.19	13.60	1.19	0.05	2.39	3.09	0.18	0.72	23.12		100.38
(4) Acid clay (Yamagata)	65.18	—	19.94	3.33	—	0.93	2.51	0.94	0.14	7.66		100.63

Source: Handbook for Clays, Japan (1967)

(2) Cation exchange capacity and some properties of bentonitic clays

Specimen	*Colour*	*pH*	*CEC* (mg eq/100 g)	*Exchangeable cations* Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	*Total*
Bentonite (Niigata)	Blue	9.4	79.8	7.2	13.2	55.6	2.9	79.8
Acid clay (Niigata)	Yellow	4.9	69.2	20.9	28.9	3.7	1.1	54.6
After Takeshi (1968)	Blue	9.2	83.3	28.7	34.9	16.5	3.5	80.1

Major world producers of fullers' earth and bentonite

Country/company	Mine/plant location	Capacity tpa	Comments
NORTH AMERICA			
Canada			
Avonlea Mineral Industries Ltd	Wilcox, Saskatchewan	60,000 sodium montmorillonite	Noranda Mines Ltd. acquired a 34.5% stake in early 1981 with an option to buy up to 51%. About 41% of output used for drilling muds and 21% as reservoir sealant
Pembina Mountain Clays	Mine near Morden, Manitoba	Calcium bentonite	Subsidiary of Filtrol Corporation which was taken over by Kaiser Aluminium and Chemical Corporation in December 1981. Ground raw material transported to acid activation plant at Winnipeg
Mexico			
Arcillas Industriales de Durango SA de CV	Mine at Cuencamé, Durango Plant at Gómez Palacio, Durango	180,000 raw clay 140,000 refined bentonite	Output in 1980 was about 120,000 tons
Quimica Sumex SA de CV	Various mines in Tlaxcala, Morelos, and Durango states. Plant at Puebla, Puebla	160,000 raw clay 50,000 refined calcium and sodium montmorillonites	Subsidiary of Süd Chemie AG of West Germany producing a variety of products under the trade name 'Tonsil'
Tecnica Mineral SA	Mines in Zacatecas, Jalisco, and Michoacan states. Plant at Tlaquepaque, Jalisco	3,000 tpa bentonite	A recent expansion programme included the installation of an acid activation plant for refined clays
USA			
American Colloid Company	Various mines in close proximity to plants at Belle Fourche, South Dakota; Upton, Wyoming; Lovell, Wyoming; and Malta, Montana	Each plant is able to produce 1,000-1,500 tpd of sodium bentonite	The company also operates a number of processing plants at other locations in the USA – Albion, Maryland (30,000 tpa); Columbus, Ohio (80,000 tpa); Granite City, Illinois (75,000 tpa); Green Bay, Wisconsin (15,000 tpa); and Waterloo, Indiana (20,000 tpa).
	Letohatchee, Alabama and Aberdeen, Mississippi	200 tpd at Letohatchee and 1,000 tpd at Aberdeen of calcium bentonite	Overseas operations include plants at Wallasey, UK (55,000 tpa); Duisburg, West Germany (60,000 tpa); Erandio-Bilbao, Spain (20,000 tpa); Geelong, Australia (25,000 tpa); Hamilton, Canada (20,000 tpa)
Anschutz Minerals Corp.	Mine and plant located at Ochlocknee, Georgia	270,000 raw clay 90,000 refined clays	Raw material consists of a mixed layer of calcium montmorillonite, diatomite, kaolin, and attapulgite. Sold for cat litter and oil absorbents
Baroid Division of NL Industries Inc.	Mines near to and plant at Colony, Wyoming	900,000 of sodium bentonite	Owns extensive reserves in Montana, South Dakota, and Wyoming. Significant amount used for in-house drilling applications
Dresser Minerals	Greybull, Wyoming mine and plant	650,000 raw clay 430,000 of sodium bentonite	About 55% of output is used for drilling mainly in-house application and the balance for iron ore pelletisation
	Rosalind, Alberta, Canada mine and plant	60,000 raw clay 40,000 of calcium bentonite	Only about 4% for drilling use
Federal Bentonite Division, Aurora Industries Inc.	Mine and plant at Colony, Wyoming	430,000 raw clay 300,000 of sodium bentonite	Produces 11 grades
	Mine and plant at Upton, Wyoming	300,000 raw clay 150,000 of sodium bentonite	Produces 15 grades
	Plant at Burnett, Minnesota	1500,000 of sodium bentonite	Produces 1 grade
	Mine and plant at Glasgow, Montana	300,000 of sodium bentonite	Currently not in operation – scheduled for start-up in 1983
Benton Clay Co	Casper, Wyoming	120,000 of sodium bentonite	Subsidiary of Georgia Kaolin Co.
International Minerals and Chemical Corp.	Colony, Crook County, Wyoming	Capacity unavailable for sodium bentonite	Mainly for drilling muds, foundry, and water retention applications
	Aberdeen, Monroe County, Missouri	Capacity unavailable for calcium bentonite	Mainly for foundries and animal feed
Industrial Mineral Ventures Inc.	Mine at Imvite, Amargosa Valley, Nye County, Nevada. Plant at Lathrop Wells, Nevada	60,000 raw clays 90,000 refined clays	Raw material comprises of bentonite, saponite, sepiolite, and mixed hectorite and calcium carbonate from which special clay product mixes are produced mainly for drilling applications as well as for sealants, fillers, suspension clays, etc

Kaycee Bentonite Corp	Mines near Kaycee and Ten Sleep with plants located at Casper and Worland, Wyoming respectively	450,000 combined plant capacity for sodium bentonite	Also known as Black Hills Bentonite Co
Lowe's Inc	Mines and plant located at Olmsted, Illinois; Paris, Tennessee; Oran, Missouri; Bloomfield, Missouri; and Maricopa, California	500,000 calcium montmorillonite absorbent clay products	
Mid-Florida Mining Co	Mines and plant near Lowell, Marion County, Florida	200,000 raw clay 130,000 refined montmorillonite attapulgite product	Raw material is essentially calcium montmorillonite and attapulgite mixture processed for absorbent clay uses
Oil-Dri Corp. of America	Mine and plant at Ripley, Mississippi and Ochlocknee, Georgia	250,000 calcium bentonite	Swiss subsidiary, Oil Dri SA, based in Zurich controls distribution in Europe
Southern Clay Products Inc	Mine and plant at Gonzales, Texas	27,000 of refined calcium bentonite	Supplies a broad range of markets such as oil well drilling, paints, inks, etc. Also produce white bentonite for cosmetics, pharmaceuticals, ceramics, etc.
Wilbur-Ellis Co	Mine at New Indria and plants at Fresno and Florin, California	35,50,000 of refined calcium bentonite	Raw material is montmorillonite with calcium and sodium in about equal proportions – a low swelling variety
Wyo-Ben Inc.	Mine and plant at Lovell, Wyoming	650,000 of sodium bentonite	Total capacity is 1,165,000 tpa of sodium bentonite, of which 500,000 tpa is crushed, dried, and granular. Current output is about 50% of capacity. Thermopolis is able to readily expand to 600,000 tpa
	Mine and plant at Greybull, Wyoming	215,000 of sodium bentonite	
	Mine and plant at Thermopolis, Wyoming	300,000 of sodium bentonite	
SOUTH AMERICA			
Argentina			
Geberovich Hnos. SCC	Mine and plant near Zapala, Neuquén Province	60,000 raw clay 12,000 ground product	Used for drilling mud, pelletisation, and foundries
Industrias Petral Srl	Seven mines in the region of Calingasta and plant at Chimbas, San Juan	30,000 bentonite product	Output is presently running at around 12,000 tpa

Brazil			
Bentonit União Nordeste SA	Mine and plant at Campina Grande, Distrito de Boa Vista, PB	240,000 capacity for sodium and calcium bentonite products	Sodium bentonite for drilling, foundries, iron ore pelletisation, civil engineering, etc. and calcium bentonite for foundries and chemicals. Bentonita Boa Vista SA is an associate company involved in bentonite exploitation at João Pessoa. Current output is around 170,000 tpa
Peru			
Minera Baribent SA	Mine at Piura, N. Peru	10,000 of raw clay	Used for drilling muds, iron ore pelletisation, and foundries
	Plant at Lima	10,000 of sodium bentonite	
Cia Minera Agregados Calcareous SA (Comacsa)	Sodium bentonite operations in Piura State, N. Peru. Calcium bentonite operation in Ica, S. Peru Plant at Lima	Total grinding capacity – 400,000	Used for foundry, animal feed, iron ore pelletisation, and shallow oil well drilling. Total recent consumption around 9,000 tpa
WESTERN EUROPE			
Cyprus			
Drapia Mining Co Ltd	Mines and plant near Drapia, Kalavasos area, Larnaca	30,000 sodium bentonite	Some raw clay is used for animal feed. Company holds extensive reserves around Drapia and has identified significant high quality deposits near Parsata
Peletico Ltd.	Mine and plant at Pentakomo	100,000 raw calcium bentonite. 60,000 sodium bentonite	Mainly used for oil well drilling and civil engineering. Investment of $2m. in 1983/84 will raise capacity to 100,000 tpa sodium bentonite
	Plant at Larnaca for grinding	30,000	
France			
Ceca SA	Mine at La Bessède and plants and Honfleur, Port-La-Nouvelle, and Le Buisson	90,000 sodium bentonite and calcium bentonite	Principally for foundries. Ceca Italiana produces bentonite on Sardinia
West Germany			
Erbsloh & Co.	Mines near Landshut and two plants at Landshut	150,000 raw clay 100,000 of sodium bentonite, and calcium bentonite	Principally for foundry applications
Sud Chemie AG	Mines in Bavaria near Freising, Mainburg, and Landshut. Plant at Moosburg, Bavaria	Capacity unavailable for sodium-exchanged and acid activated bentonite	Europe's leading producer of all varieties of bentonite. The company controls subsidiary operations in Mexico (Quimica Sumex SA de CV, Tonsil Mexicana SA de CV); Italy (Süd Chemie Italia SpA); and France (Sté Française des Bentonites et Dérivés Sarl)
Greece			
Mediterranean Bentonite Co Ltd	Mine on Milos Island, Greece	300,000 raw clay	Subsidiary of Industria Chimica Carlo Laviosa della Carlo Laviosa SpA. Capacity determined by loading capability of 800 tons a day at the port of Adamas
Mykobar Mining Co SA	Mine on Milos Island	120,000 raw clay	Subsidiary of Dresser Industries Inc. Mainly for oil well drilling and iron ore pelletisation
	Plant at Adamas Bay, Milos	60,000 sodium bentonite	
	Plant at Aghia Anna	5,000 sodium bentonite	
Silver and Baryte Ores Mining Co.	Mine on Milos Island Plant at Voulthia Bay	350,000 raw clay 400,000 sodium bentonite	Mainly for iron ore pelletisation and also oil well drilling and foundries
Israel			
Negev Ceramic Materials Ltd.	Mine at Ramon Crater, Negev	40,000 raw clay	Clay consists of 60% montmorillonite, 20% illite, 20% kaolin, calcium carbonate etc. Current output is 15,000 tpa for animal feed mainly
Italy			
Ditta Dott. Settimio Cinicola Industria Mineraria	Mines in Foggia and Campobasso Districts. Plant in Castelnuovo della Daunia, Foggia District	50,000 sodium and calcium bentonite	
Industria Chemica Carlo Laviosa della Carlo Laviosa SpA	Mines at Pedra de Fogu and Puntenuovo, Sardinia		Recently set up a 20,000 tpa processing plant at Port le Valence on the Rhône to supply the French foundry industry in the south-central region
	Plant at Villacidro, Cagliari, Sardinia	40,000 bentonite	Operated by Soc. SVI MISA
	Plant at Santa Giusta, Oristano, Sardinia	165,000 sodium and calcium bentonites	Operated by Mineraria Chimica Sarda SpA
	Plant at Livorno	142,000 sodium and calcium bentonites	The company's main plant which may be increased by a further 82,500 tpa
Caffaro SpA	Mines in northern Sardinia. Plant at Porto Marghera	20,000 acidified calcium bentonite	Produces treated montmorillonite bleaching earths for decoloration of vegetable and animal oils and fats etc.

Ceca Italiana SpA	Mines in Sardinia	50,000 raw clay	Subsidiary of Ceca SA
Edemsarda SpA	Mine at Mandas, Trexenta and plant at Cagliari, Sardinia	150 tpd sodium bentonite	Mainly for oil well drilling in N. Africa and the Middle East
Sardamin Srl	Mine and plant at Torrabia, Sardinia	20,000 bentonite	Expansion to 35-40,000 tpa by 1984
Baroid International SpA	Mines at Nurallao and Giba Plant at Sant' Antioco	40,000 sodium bentonite	Subsidiary of NL Industries Inc.
Elba SpA	Mine at Arsiero, Vicenza	15,000 raw clay	
Sta Mineraria Estrattiva Srl	Mine and plant at Pietracuta di S. Leo, Pesaro	25,000 sodium bentonite	
Sud Chemie Italia SpA	Mine and plant at Piscinas, Ciba, Sardinia	110,000 sodium bentonite	Subsidiary of Süd Chemie AG
Valdol SpA	Mine and plant at Maglio di Sopra	60,000 raw clay 50,000 bentonite	Products mainly for foundries and oil well drilling uses
	Mine at Recoaro	10,000 raw clay	
	Mine at S. Giovanni	10,000 raw clay	
	Plant t Altavilla Vicentina	25,000 bentonite	
Spain			
Minas de Gador SA	Mine and plant at Almeria	90,000 sodium bentonite and 12,000 acid activated bentonite	Laporte Industries hold 40% interest
	Mine and plant in Yuncas, Toledo	12,000 bentonite	Mainly for foundries and animal feed
Turkey			
Basik Ates Tugla Sanayii ve Ticaret Ltd Sti	Mine at Arnavutkoy, Istanbul	10,000 raw clay	
Emko Bentonit Ticaret ve Sanayi AS		30,000 raw clay	
Kale Madencilik & Kale	Mines at Cankiri and plant at Esenboga Mine at Tokat		
Turan Madencilik Sanayi ve Ticaret Ltd.	Mines in the Eskişehir district and plant at Kepsut-Balikesir, Eskişehir	11,000 calcium and sodium bentonites and acid activated clay	A new 60,000 tpa sodium bentonite plant and 15,000 tpa acid activated plant is under construction at Kepsut-Balikesir
United Kingdom			
Brett Bentonite Ltd.	Mine and plant at Baulking, Oxfordshire	50,000 sodium bentonite	Subsidiary of Robert Brett & Sons Ltd
Laporte Industries Ltd.	Mine and plant at Redhill, Surrey	190,000 sodium and calcium bentonite	Interest held in Minas de Gador, Spain (40.25%); Bentonit Uniao Nordeste SA, Brazil (40%); Bentonita Boa Vista SA, Brazil (40%). Also has other deposits in the UK at Maidstone, Kent, Bath, Avon; and Clophill, Bedfordshire
	Plant at Widnes, Cheshire	30,000 acid activated calcium bentonite	
Steetley Minerals Ltd.	Mine and plant at Woburn Sands, Bedfordshire	50,000 sodium and calcium bentonite	Subsidiary of Steetley Industries Ltd.
FAR EAST			
India			
Ambica Minechem Industries	Mines in Kutch and Bhavnagar districts and plants at Bhavnagar and Gandhidham, Gujurat State	40,000 sodium bentonite	
Ashapura Minechem Industries	Mines and plant in Kutch and Bhavnagar District of Gujurat State	90,000 sodium bentonite	Production scheduled to reach 100,000 tpa by end 1983
Atul Mining Works	Mine near Bhawanimandi, Rajasthan State	3,500 bentonite	
Bombay Sewree Chemicals Manufacturing Co. Pvt Ltd.	Mines and plant at Sewree, Bombay. Two plants at Vapi, Gujurat State	3,300 acid activated fuller's earth	Recent output – 2,150 tpa for western Indian markets
Chaturbhuj Naranjee	Mine and plant at Kutch, Mandvi, Gujurat State	25,000 sodium bentonite	For oil well drilling, foundries, iron ore pelletisation
Gandhisons	Mines at Kutch, Gujurat State		
Gimpex Minerals Pvt. Ltd.	Mines at Mandvi Tuluk and plant at Gandhidam, Gujurat State	20,000 sodium bentonite	Current output is around 12/15,000 tpa
Hargovindas Shivlal & Co.	Mine at Kutch, Gujurat and plant at Chembur, Bombay	2,500 sodium and calcium bentonite	
Kasamali & Sons Minerals	Mine at Bhavnagar, Gujurat State	20,000 bentonite	

Kutch Minerals	Mines at Mutch and plants at Kutch-Mandvi and Gandhidam, Kutch, Gujurat State	30,000 sodium bentonite	Several associated companies produce more than 40,000 tpa of ground bentonite (Suraiya Minerals & Chemicals Pvt Ltd., I. David & Co. Pvt Ltd., Suraiya Pvt Ltd., Kutch Clays, and Kutch Oil & Allied Industries (1939) Pvt Ltd.)
Neelkanth Chemical Works	Mines at Akli, Hathikidhani, and Bisala, Barmer District, Rajasthan and plants at Barmer and Jodhpur	25,000 sodium bentonite	Mainly for foundries, oil well drilling, and civil engineering
Rajasthan State Mineral Development Corp Ltd.	Mine and plant at Akli, Barmer District, Rajasthan State	500 sodium bentonite	
Japan			
Hojun Kogyo Co. Ltd.	Mines near Tom[illegible]shi and Myogi-machi and at Annaka-shi Plants at Annaka and Haraichi	180,000 bentonite	Current output is around 132,000 tpa mainly for foundries, civil engineering, and insecticide carriers
Kunimine Industries Co. Ltd.	Mines at Tsukinuno, Yamagata Pref. and Kawasaki, Miyagi Pref.	205,000 raw clay	For oil well drilling, foundries, civil engineering, and pesticides
	Plant at Aterazawa, Yamagata Pref.	150,000 sodium bentonite	
	Plant at Zao, Miyagi Pref.	12,000 calcium bentonite and 40,000 acid activated bentonite	Mainly for foundries For foundries exclusively
Mizusawa Industrial Chemicals Ltd	Mines at Tsuruoka, Yamagata Pref. and Nakajo and Shibata, Niigata Pref.	150,000 acid clay	Calcium bentonite raw material is acid activated for the refining of oils and fats etc.
	Plant at Tsuruoka, Yamagata	15,000 acid activated clay	
	Plant at Nakajo, Niigata	60,000 acid activated clay	
Kuroishi Bentonite Co. Ltd.	Mine and plant at Kuroishi, Aomori Pref.	50,000 raw clay 50,000 sodium bentonite	Output in 1980 - 18,000 tons, last year of full production prior to liquidation in November 1981. Subsequently taken over from Mitsui Mining & Smelting by Nihon Kousan Co. Ltd.
Philippines			
Jose Pantoja & Co.	Mine at Sabang, Danao City	20,000 raw clay	
A & C Industrial Inc	Mines at Laguna and Batangas Plant at San Pablo City	2,000 raw clay	White clay for foundries and steel mainly
Falcon Minerals Inc.	Mine at Nueva Ecija, Luzon	30,000 raw clay	
	Plant at Metro Manila	12,000 sodium bentonite	
Filmag (Philippines) Inc.	Mine in northwestern Leyte	11,000 raw clay	
	Plant in Barrio Can-Unzo, Merida, Leyte	40,000 sodium bentonite	
AUSTRALASIA			
Australia			
Cudgen R.Z. Ltd	Mines at Gurulmundi and Woleebee, near Miles in Southwest Queensland and plants at Gurulmundi and Brisbane	50,000 sodium bentonite	Currently undergoing expansion of Brisbane plant to 150,000 tpa. Mainly for oil well drilling, water well drilling, civil engineering, foundries, pelletisation, and animal feed
Steetley Industries Ltd. (Australia) Minerals Group	Mine at Wingen, New South Wales and plant at Newcastle, New South Wales	Current production is around 6,000 tpa of bentonite	Deposit consists of 8 layers of calcium bentonite in upper Permian sediments. Mainly for foundries and civil engineering uses
New Zealand			
Canterbury Bentonite Ltd.	Mine and plant at Coalgate, Canterbury Plains	30,000 granular sodium bentonite and 8,000 fine ground sodium bentonite	Subsidiary of Mintech (N.Z.) Ltd. Some calcium bentonite is also produced but main uses for sodium bentonite are drilling muds, civil engineering, and foundries
AFRICA			
South Africa			
G & W Base and Industrial Minerals (Pty) Ltd.	Mines near Parys, northern Orange Free State. Plant at Wadeville, Germiston, Transvaal		
Cape Bentonite (Pty) Ltd.	Mine and plant at Heidelburg, Cape Province	50,000 raw clay 30,000 sodium bentonite	Associate company to Metallgesellschaft (SA) (Pty) Ltd. Production based on naturally occurring sodium bentonite
	Plant at Germiston, Transvaal	10,000 sodium bentonite	
Tanzania			
Tanganyika Meerschaum Corp Ltd	Mines at Sinya, northern Tanzania	Capacity unavailable	Used domestically for oil well drilling, foundries, and civil engineering

539010

World bentonite production (mil m tons) .

Mineral Trade Notes July 1979 p. 7

Region	Country(a)	1977	1978
N America	Guatemala	--	.003
	Mexico	.059	.034
	US	3.399	4.053
S America	Argentina	.145	.145
	Brazil	.108	.100
	Colombia	.001	.001
	Peru	.042	.045
Europe	France	.022	.022
	Greece	.419	.348
	Hungary	.080	.082
	Italy	.280	.224
	Poland	.050	.050
	Romania	.063	.065
	Spain	.110	.110
Africa	Algeria(b)	.024	.031
	Morocco	.005	.005
	Mozambique	.003	.003
	S Africa	.037	.035
	Tanzania	.00004	.00002
Asia	Burma	.001	.001
	Cyprus(c)	.013	.007
	Iran	.050	.050
	Israel	.008	.008
	Japan	.400	.400
	Pakistan	.001	.001
	Philippines	.002	.002
	Turkey	.004	.010
Oceania	Australia(d)	.012	.015
	New Zealand(e)	.001	.001
Total		5.341	5.849

(a) Austria, Canada, China, W Germany and the USSR produce bentonite b
output is not reported & information is not reliable. (b) bentonitic clay,
(c) includes bentonitic clay, (d) includes bleaching earths. (e) processed

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BENTONITES

Geology, Mineralogy, Properties and Uses

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Chapter 1

INTRODUCTION

The name bentonite was suggested in 1898 by Knight for a peculiar clay-like material with soapy properties from its occurrence in the Fort Benton unit of Cretaceous age formations in Wyoming (U.S.A). Hewitt (1917) and Wherry (1917) first established that this particular clay is an alteration product of volcanic ash, although an earlier observation by Condra (1908) suggested this origin for a similar clay from northern Nebraska. Ross and Shannon (1926) presented the following definition which has been widely quoted: "Bentonite is a rock composed essentially of a crystalline clay-like mineral formed by the devitrification and the accompanying chemical alteration of a glassy igneous material, usually a tuff or volcanic ash". These authors further stated that, "the characteristic clay mineral has a micaceous habit and facile cleavage, high birefringence, and a texture inherited from the volcanic tuff or ash, and it is usually the mineral montmorillonite, but less often beidellite". The term bentonite is now well established (Wright, 1968) for any clay which is composed dominantly of a smectite clay mineral, and whose physical properties are dictated by this clay mineral; this is the definition used in this volume.

As indicated later in this volume, there are many clays now designated as bentonite which have not originated by the alteration of volcanic ash or tuff, or whose origin cannot be established definitely. Consequently, the definition of bentonite used herein does not include mode of origin.

The term fuller's earth refers to any natural material which has the capacity to decolorize oil to an extent to be of commercial value. The term does not imply any mode of origin, or any particular mineral composition. However, fuller's earths are generally composed of attapulgite or a smectite clay mineral, although not all clays composed of these clay minerals have the decolorizing capacity necessary for their classification as fuller's earths.

The unique physical properties of the Wyoming clay quickly gave it high commercial value. Its use in oil well drilling muds, as a bonding agent for foundry molding sands, and in other commercial processes caused the development of an important bentonite producing industry in Wyoming, and led to a search in other regions for similar clays with the same properties. Such clays were soon found in Mississippi, Texas, Arizona, and California of the U.S.A., and in England, Germany, U.S.S.R., Japan, and many other countries. A bentonite producing industry developed rapidly outside of the United States beginning in the late 1920's. Grim has had an opportunity for many years to visit and study the occurrence of bentonites in many parts of the world. Samples were collected from many of the deposits visited, and

additional samples from other deposits were kindly supplied by friends and colleagues. A collection of approximately 1,000 world-wide bentonite samples was developed and is now housed in the Department of Geosciences at Texas Tech University in Lubbock, Texas. Much information was gathered in the field on the mode of occurrence of bentonites, including the types of formations with which they are associated, their relationship to hydrothermal and/or deuteric activities, and their association with unaltered volcanic ash, tuff, or other volcanic material.

The first objective of this volume is to describe the geologic and geographic occurrence of bentonites world-wide. No claim is made that all known deposits are listed, but it is hoped that no large significant deposits have been overlooked. The information recorded is from the literature and from data obtained by one of us (Grim) on visits to many of the deposits in the field.

It is obviously impossible to list all available references to the various deposits. An attempt was made to select papers of general interest that especially were concerned with occurrence and origin of the bentonites. There are many additional publications which are concerned with the properties and uses of particular bentonites.

Very limited information regarding bentonites is available for some countries, e.g. China, Cuba, Colombia. Consequently, it should not be concluded from the brief statements regarding some countries that substantial deposits of bentonites may not occur there or may be unknown. Similarly, there are other countries for which no reference to bentonite could be found, e.g. Chile, but based on geological considerations, it seems likely that bentonites should be present in some of these countries.

No mention is made regarding the so-called metabentonites, i.e. clays probably of volcanic origin, usually of Paleozoic age, which are composed of illite-smectite mixed-layers, and which do not have the colloidal properties associated with the term bentonite.

The second objective of the volume is to consider the variations in the mineral and chemical composition of bentonites. Detailed mineralogical analyses of the samples have been made by Güven. Because of the submicron crystallite size and poor crystallinity of the major component (smectite) in bentonites, X-ray diffraction analyses were of limited use. Therefore, modern electron-optical methods were used extensively in studying the morphology and structure of the smectite particles.

Members of the montmorillonite—beidellite series form the smectites commonly occurring in bentonites. The smectites are examined with respect to their atomic structure, chemical composition, and crystal morphology (habit, particle size, and mode of aggregations). Electron optics, which are probably the most powerful methods for precise analyses of the above properties of smectites, are discussed in detail. An attempt is made to classify the smectite particles according to their morphological character-

istics. The habit of single crystallites and the morphological features of smectite aggregates are discussed with respect to crystal growth mechanisms and to the factors governing crystal growth processes.

The chemistry of smectites is examined using a rapid method of analysis by atomic absorption spectroscopy and a single-solution decomposition technique. The problems related to the calculation of chemical formulae for smectites are discussed. 152 chemical analyses of smectites are compiled from the literature and subjected to a factorial analysis in order to elucidate the correlations between the chemical components in these minerals.

The third, and last, objective is to consider the physical properties of bentonites, and the manner in which the physical properties determine the commercial usage of these clays. An attempt is made to correlate the properties with the fundamental mineral and chemical character of the bentonites.

REFERENCES

Knight, W.C., 1898. Bentonite. Eng. Min. J., 66: 491.

Hewitt, D.F., 1917. The origin of bentonite. J. Wash. Acad. Sci., 7: 196–198.

Wherry, E.T., 1917. Clay derived from volcanic dust in the Pierre of South Dakota. J. Wash. Acad. Sci., 7: 576–583.

Condra, G.E., 1908. Geology and water resources of a portion of the Missouri River valley in northwestern Nebraska. U.S. Geol. Surv., Water-Supply Pap., 215: 59 pp.

Ross, C.S. and E.V. Shannon, 1926. Minerals of bentonite and related clays and their physical properties. J. Am. Ceram. Soc., 9: 77–96.

Wright, P.C., 1968. Meandu Creek bentonite — a reply. J. Geol. Soc. Aust., 15: 347–350.

3.3. BENTONITES IN AFRICA

Valuable bentonite deposits are located in many parts of Africa with important commercial production in Morocco, Algeria, Union of South Africa, and Mozambique.

Algeria and Morocco

Geological features. These two north African countries are considered together because of the similarity of their geologic setting and bentonite occurrences. In general the areas containing the bentonites are in the northern part of the countries and consist of a series of Cretaceous and Tertiary sediments with interbedded pyroclastics and lava flows, and into which volcanic rocks of varying composition have been intruded. Bentonites of varying types and modes of origin occur in these rocks, and they have been extensively developed commercially at several places. Following are examples of these deposits, but not a complete presentation of all deposits.

In Algeria, about 25 miles east of Mostaganem along the Chelif River, a series of five separate bentonite beds occur interlayered with ashy silts of Miocene age, Fig. 3.30A (sample 46). Ash structures are preserved in the bentonite indicating its mode of origin. The bentonite beds, varying in thickness from 5 inches to 15 ft., are not sharply separated from the silt. There is no silification of underlying beds, nor any suggestion of downward leaching. The fresh bentonite is blue, quickly weathering to brown, and contains many "egg" structures similar to those found in the Wyoming, U.S.A. material. The weathered brown clay is said to have higher colloidal properties than the blue bentonite. Some of the bentonites carry sodium as the dominant exchange cation rather than calcium, which is interesting in view of its interlamination with calcareous sediments. The cation exchange composition together with the gradational contact with the enclosing beds suggest that alteration of the ash was contemporaneous with accumulation. Diatomaceous earth is found in the same area in sediments of the same age.

At Lalla Maghnia in the Oran area of Algeria, a rhyolite plug occurs in a Tertiary marine sequence. At some places the rhyolite has altered to smectite, at other places to kaolinite or halloysite. Sadran et al. (1955) attribute the formation of this deposit to hydrothermal alteration of the rhyolite. The texture of the rhyolite is retained in the clay and the volume is unchanged, even though the chemical composition of the smectite and rhyolite indicate that magnesium has been added and alkalies and silicon have been removed in the transition. The hydrothermal action is believed to have been followed by the circulation of magnesium-bearing waters, probably meteoric, which added the magnesium and leached the alkalies and silicon.

On the south side of the Tafna Valley about 10 miles from Tyrene in Algeria, five beds of bentonite — 3 inches to 15 ft. thick — are found inter-

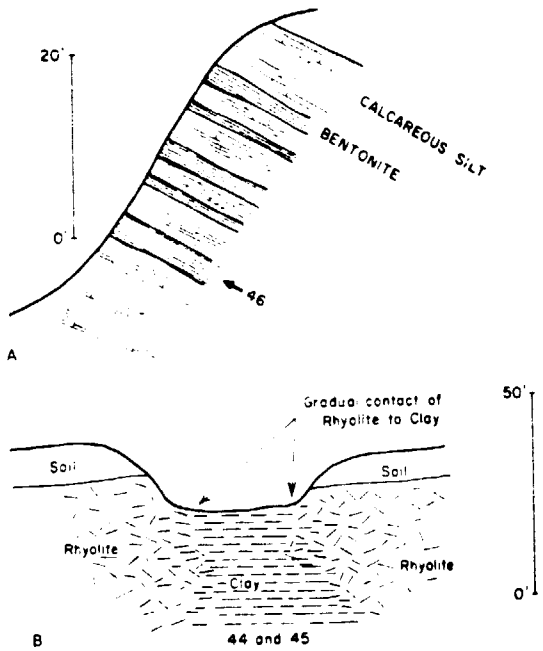

Fig. 3.30. A. Section of Miocene age formations in Chelif Valley, 5 km north of Bellevue in Mostaganem area, Algeria. B. Clay deposit northeast of Marnia in Nemours area, Algeria.

bedded with calcareous brown silts of Miocene age. The bentonite is white and contains occasional fragments of rhyolite. There is no silicification of underlying beds nor any evidence of leaching. There are intrusive masses of rhyolite and basalt nearby. Deuteric alteration of rhyolitic material is the probable mode of origin.

About 4 miles north of Marnia in Algeria on the road to Nemours and thence 5 miles east, there is a large deposit of bentonite which supplied the clay for the production of acid activated decolorizing [illegible]t the plant in Marnia. A dike of rhyolite dipping about 60° cuts thr[illegible] sequence of Miocene sediments (Fig. 3.30B). The central part of th[illegible] is altered to clay, preserving the texture of the rhyolite (samples 44 and 45). The clay is white and translucent in appearance. The composition of the clay is quite variable and ranges from pure montmorillonite to material with considerable halloysite. Probable factors controlling the composition are not obvious. Hydrothermal or possibly deuteric processes are possible modes of origin of the clay minerals. As in the case of the deposit at Lalla Maghnia, the alteration must have been accompanied by the addition of magnesium and the removal of silicon and alkalies.

Termier et al. (1956) have described bentonites of varying modes of origin between Menerville and Dra-el-Mizane in Algeria. Some of the bentonites are interbedded with obsidian and are believed to be due to autopneumatolytic (deuteric) action in rhyolitic material. Other occurrences in sediments suggest alteration of volcanic breccia in a saline lacustrine environment.

There are many occurrences of bentonite in the Taourirt area of Morocco. The Gara Zjad deposit about 15 miles northeast of Taourirt consists of layers of bentonite about 2 inches thick in a Miocene section of bentonitic clays, volcanic ash, and marine fossiliferous sand. The bentonite grades upward into ash, and the association of bentonite beds with unaltered ash beds are of interest, as the upward gradation of bentonite to ash precludes origin by a weathering process. Perhaps the ash fell in very shallow water with only the wetted ash altering to bentonite, or possibly the composition of the ash was not constant — the earlier lower ash being wetter or different in chemical composition from the later ash. The Miocene section is overlain by about 30 ft. of gravel. Many of the hills in the area are capped by basalt of Pliocene age.

At Camp-Berteaux, also in the Taourirt area, beds of bentonite are found in a marine Miocene fossiliferous sequence (sample 47). The Taourirt bentonite is said to have outstanding properties for decolorizing oil. Current bentonite production is reported at Tamdafelt and in the Beni Aukil districts.

Mineralogical studies. In the bentonite (sample 44) from Marnia (Algeria), montmorillonite carries largely magnesium with relatively smaller amount of sodium as indicated by the data on extractable cations in Table 3.3A. Smectite particles in this sample are commonly in the form of (Cheto-type) mossy aggregates. In the other sample from Marnia (sample 45), montmorillonite particles occur mostly in the form of (Santa Rita-type) reticulated lamellar aggregates. The bentonite from Tafna contains Cheto-type aggregates as the common form of montmorillonite. As shown in Fig. 3.31, these aggregates are often entangled with lath shaped units. These laths seem to grow from the montmorillonite aggregates. Kaolinites are also found in the sample in the form of hexagonal platelets that are often in edge-to-edge association. In the bentonite from Mostaganem, Algeria, sample 46, smectite particles occur mainly in the form of Cheto- and Santa Rita-type aggregates, with H- and L-type particles occurring rarely. The smectite has the structural formula:

$$[(Si_{3.96}Al_{0.04})(Al_{1.56}Fe^{3+}_{0.11}Mg_{0.33})O_{10}(OH)_2]M^{+}_{0.37}$$

In all the above bentonites from Algeria, quartz, mica, and feldspars form the common impurities.

The bentonite from Camp-Berteaux, Morocco (sample 47) contains a montmorillonite with a basal spacing of 14.7 Å. Na, Ca, Mg are about equally present in the extract of exchangeable cations from this sample

TABLE 3.3A

Location, geological and mineralogical data on bentonites from Africa

Sample no.	Location and formation	Geologic age	Smectite's spacings (Å)	Mg() * (%)	Extractable cations (mequiv./100 g)	C.E.C. (mequiv./

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TABLE 3.3A

Location, geological and mineralogical data on bentonites from Africa

Sample no.	Location and formation	Geologic age	Smectite's spacings (Å)		MgO * (%)	Extractable cations (mequiv./100 g)					C.E.C. (mequiv./100 g)
			(001)	(06,33)		Mg	Ca	K	Na	total	
	Algeria										
44	Marnia	Pliocene	14.3	1.496	3.94	61	18	2	35	116	
45	Marnia	Pliocene	15.0	1.496	3.22 +						
46	Mostaganem, Bellevue	Miocene	13.8	1.496	3.81	61	5	3	28	97	
	Morocco										
47	Camp Berteaux	Miocene	14.7	1.497	4.24	58	59	2	57	176	109
	Union of South Africa										
48	Natal, Zululand, Stormberg Series, "Mkuzi green"	Liassic	12.3	1.493	0.82	20	6	2	20	48	
49	Natal, Zululand, Stormberg Series, "White"	Liassic	12.2	1.495	1.67	47	14	1	35	97	
50	Orange Free State, Parys, Karoo System "Ocean"	Liassic	12.5	1.500	3.98	44	60	1	120	225	103
51	Orange Free State, Parys, Karoo System "Ocean top"	Liassic	13.6	1.500	3.55	6	42	2	3	53	
52	Orange Free State, Parys, Karoo System "Ocean bottom"	Liassic	15.0	1.497	4.77	46	45	2	7	100	
53	Orange Free State, Parys, Karoo System "Ocean middle"	Liassic	14.4	1.499	3.96	55	64	2	7	128	128
54	Cape Province, Plettensberg Bay	Tertiary	15.0	1.501	4.89	14	127	2	5	148	57
	Mozambique										
55	Laurenco Marques, Stormberg Series, "ultra white"	Liassic	12.3	1.497	0.93	32	8	1	32	73	
56	Laurenco Marques, Stormberg Series, "perlite"	Liassic	12.3		3.52						
57	Laurenco Marques, Stormberg Series, "portal"	Liassic	12.6	1.497	1.17	21	7	1	22	51	

* On ignited material from −1 μm fraction of clay stripped off exchangeable cations.
+ Grim and Kulbicki (1961) on 110°C basis.

TABLE 3.3B

Chemical analyses of African bentonites (on ignited material from −1 μm fractions of ammonium saturated clays except for the data from the literature)

Sample no.	SiO_2	Al_2O_3	Fe_2O_3	MgO	Li_2O	Na_2O	CaO	K_2O	Total	Impurities *
44	69.34	23.62	1.85	3.94	0.0	0 01	0.03	0.02	98.81	Q(5)
45 **	63.37	23.37	3.82	3.22	0.0	0.0	0.63	0.0	94.88	—
46	68.47	23.55	2.55	3.81	0.0	0.02	0.04	0.09	98.53	—
47	67.01	24.92	2.56	4.24	0.0	0.06	0.04	0.21	99.04	—
48	71.39	24.20	2.25	0.82	0.0	0.03	0.03	0.03	98.75	crist(30) kaol(10)
49	68.93	25.60	3.02	1.67	0.0	0.03	0.04	0.03	99.32	crist(5) kaol(5)
50	63.64	27.92	4.78	3.98	0.0	0.03	0.05	0.32	100.72	Q(5)
51	67.83	22.35	5.35	3.55	0.0	0.01	0.05	0.39	99.53	—
52	62.18	28.78	4.42	4.77	0.0	0.01	0.01	0.12	100.29	Q(5)
53	66.26	22.19	5.60	3.96	0.0	0.02	0.05	0.42	98.50	—
54	67.06	23,72	1.67	4.89	0.0	0.11	0.33	1.60	99.68	feldspar (10)
55	88.92	8.67	1.02	0.93	0.0	0.01	0.02	0.02	99.59	crist(60)
56	73.74	18.24	3.65	3.52	0.0	0.03	0.16	0.13	99.47	crist(20)
57	84.77	11.33	1.20	1.17	0.0	0.01	0.01	0.09	98.58	crist(60)

* Impurities are semiquantitatively estimated from the X-ray diffraction data. (crist = cristobalite; kaol = kaolinite; Q = quartz.)
** Grim and Kulbicki (1961) on the −2 μm fraction of H-clay.

Fig. 3.31. Montmorillonite aggregates and lath-shaped units associated with them in bentonite from Tafna, Algeria.

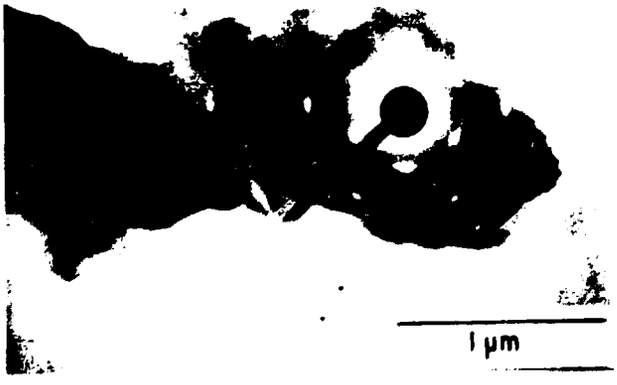
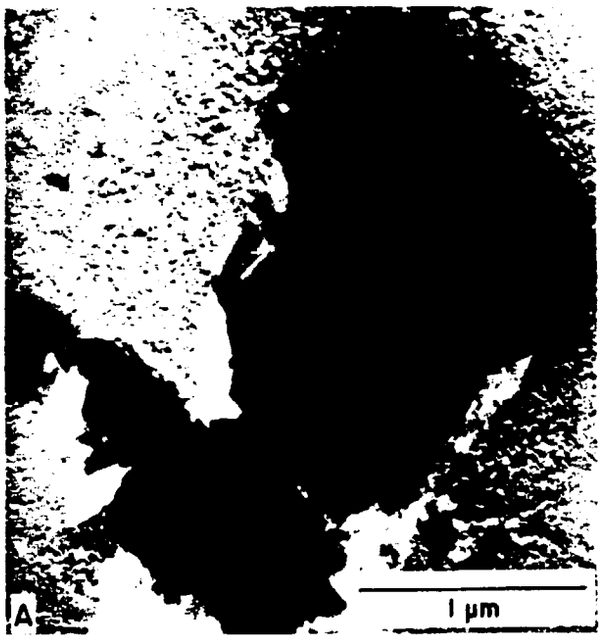


Fig. 3.32. A compact montmorillonite aggregate in the Camp-Berteaux sample with its superimposed SAD pattern.



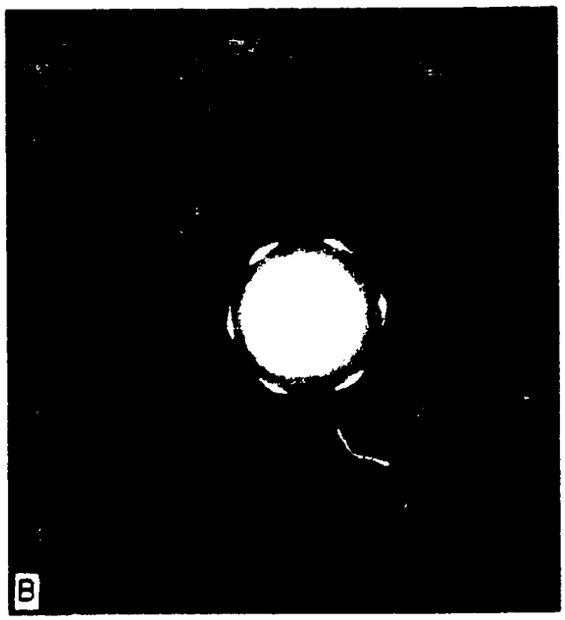


Fig. 3.33. A. Typical compact aggregates of Camp-Berteaux montmorillonite. B. The SAD pattern of the larger particle in the previous figure displaying strong secondary textures along the [02], [11], and [$\bar{1}$1] directions.

(Table 3.3A). However, the cation exchange capacity (109 mequiv./100 g) and 14.7 Å basal spacing suggest that some of the extractable sodium and magnesium probably originate from other minerals in the sample rather than from the smectite. The chemical formula of this smectite is calculated from the data in Table 3.3B to be:

$$[(Si_{3.84}Al_{0.16})(Al_{1.53}Fe^{3+}_{0.11}Mg_{0.36})O_{10}(OH)_2]M^{+}_{0.52}$$

Electron-optical observations on Camp-Berteaux sample show that montmorillonite particles occur mostly in the form of aggregates that are compact in appearance (Figs. 3.32 and 3.33A), and in which individual crystallites are not discernable. The SAD patterns indicate a strong preferred orientation in the arrangement of the crystallites along the [02], [11], and [1$\bar{1}$] directions as shown in Figs. 3.32 and 3.33B. The individual crystallites of smectites are occasionally observed as E- or S-type lamellae after the dispersion treatment.

Union of South Africa

Geological features. Bentonites are known and produced commercially from several places in South Africa. Several beds up to 8 ft. thick interbedded with shales and sands are found in formations of the Karoo System of Liassic age in the vicinity of Parys in the Orange Free State (samples 50, 51, 52, and 53). These beds carrying calcium as the exchangeable cation are composed of substantially pure montmorillonite. It is interesting to note that these bentonites show no relict structures nor non-smectite minerals indicating parent volcanic ash. Also, there is no evidence of any volcanic activity in the region at this interval in geologic time. The beds are sharply bounded at their base, but gradational through a short interval to the overlying shale. The underlying beds are not silicified.

At numerous places in the Cape Province along the Indian Ocean, there are inliers of Tertiary formations from the coast westward. These beds of sands, clays and shales contain layers of bentonite at several localities. For example, in the vicinity of Plettensberg Bay, there are lenticular beds of very pure montmorillonite up to 6 ft. thick in a shale section (sample 54). Similarly in the vicinity of Albertinia to the south, there are beds of similar thickness which in some instances are relatively pure montmorillonite, while other beds contain considerable illite, quartz, and other minerals. These Tertiary bentonites are sharply separated from underlying beds, but gradational with overlying soft shales. There is no silicification of the underlying beds, and they are similar to the bentonites from the Orange Free State in that there are no relict structures in the bentonite, and no evidence of volcanic activity in the region at the time of their formation.

An interesting occurrence of bentonite is found in northern Zululand in the Natal Province (samples 48, 49). Here a glassy, perlitic, rhyolitic lava in a volcanic sequence near the top of the Stormberg Series of the Karoo System

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in places is altered by deuteric action to smectite. The alteration of the perlite to smectite is extremely irregular. At some places the perlite is completely unaltered; at other places, the alteration is so complete that there are pockets of almost pure smectite; at still other places, the smectite is scattered through the glass, or the perlite contains disseminated smectite. Occasionally the alteration product is kaolinite or a mixture of kaolinite and smectite with some cristobalite. There is no suggestion of any variation with fractures or the penetration of hydrothermal agents from outside sources. It seems clear that the alteration took place as a consequence of reactions between gases and vapors included within the parent igneous rock and the perlite, and was concentrated where the gases and vapors were most abundant. The geologic setting and character of this deposit are similar to those that will be described in Mozambique (see pp. 71—72).

Mineralogical studies on the bentonites from Natal Province, Zululand. The X-ray diffraction data (Table 3.3A) indicate the presence of a Na-montmorillonite with basal spacings of 12.3 and 12.2 Å (samples 48, 49). Large amounts of magnesium are, however, found among the extractable cations. Some of this magnesium might originate from biotites in these samples. Samples 48 and 49 contain about 50% and 20% cristobalite respectively in their coarser (>10 μm) fractions. These large amounts of cristobalite may account for the low values of total extractable cations. Kaolinite is also present in small quantities (5—10%) in these samples. The cristobalite is still a major component in the fine fractions (−1 μm) of the sample 48 as indicated in Table 3.3B. The latter table also shows that the magnesium contents of these smectites are below 2% even after accounting for the cristobalite in the samples, and consequently, these smectites are to be specified as beidellites.

Electron-optical examination of sample 48 shows that Cheto-type aggregates make up about 70% of the smectite particles. The S-type lamellae are the next common form of smectites in the sample. Aggregates of cristobalite and montmorillonite are frequently observed.

In the "white clay" (sample 49), montmorillonite aggregates display tree-like branchings similar to those of dendrites. Such an aggregate is shown in Fig. 3.34, in which triangular smectite lamellae are developed at the tips of the branches like the leaves of a tree. Such dendritic aggregates make up about 70% of the smectite particles, the E- and S-type lamellae make up the remainder. These E-type lamellae are shown in Fig. 3.35. The smectites of the dendritic (tree-like) aggregates, E-, and S-type lamellae all have a *b*-dimension of 9.00 ± 0.02 Å.

Mineralogical studies on the bentonites from Parys, Orange Free State, Plettensberg Bay, Cape Province. Sample 50 was a commercial product pretreated with Na_2CO_3. The analytical data on the sample in Table 3.3 indicate a basal

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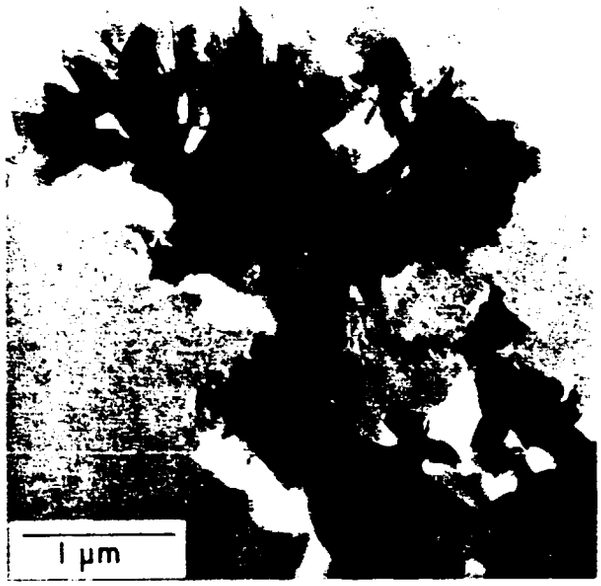

Fig. 3.34. Dendritic aggregates of montmorillonite in sample 49, Zululand, Natal Province, South Africa.

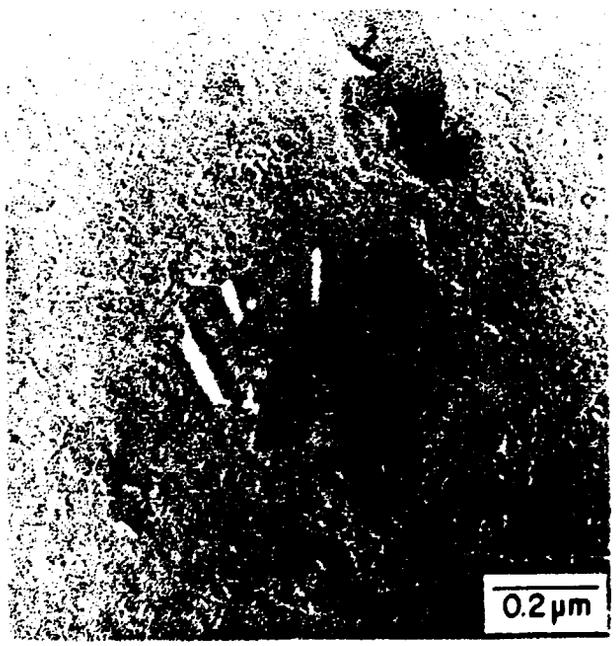

Fig. 3.35. Two E-type montmorillonite lamellae (in center), and S-type lamellae in Mkuzi bentonite (sample 49), Natal Province, South Africa.

spacing of 12.5 Å as expected from a Na-montmorillonite. Large amounts of Ca and Mg are also found among the extractable cations in the same sample, probably originating from other minerals than the montmorillonite. A predominantly calcium bearing montmorillonite occurs in samples 51 and 54. Smectites in samples 52 and 53 carry both calcium and magnesium as exchangeable cations. The smectites have the following formula in samples 51 and 53, as calculated from the data in Table 3.3B:

Sample 51: $[(Si_{3.91}Al_{0.09})(Al_{1.45}Fe^{3+}_{0.24}Mg_{0.31})O_{10}(OH)_2]M^{+}_{0.40}$

Sample 53: $[(Si_{3.88}Al_{0.12})(Al_{1.41}Fe^{3+}_{0.25}Mg_{0.35})O_{10}(OH)_2]M^{+}_{0.47}$

Quartz, mica, kaolinite, and feldspars are the common impurities in the above samples from Parys. The sample from Cape Province (sample 54) contains, in addition, about 20% cristobalite in the coarser fractions (>10 μm).

Electron-optical observations show that Chato- and Wyoming-type aggregates, H-, S-, and L-type particles are equally common forms of smectites in sample 50. In the top layer of the Parys bentonite (sample 51), Wyoming-

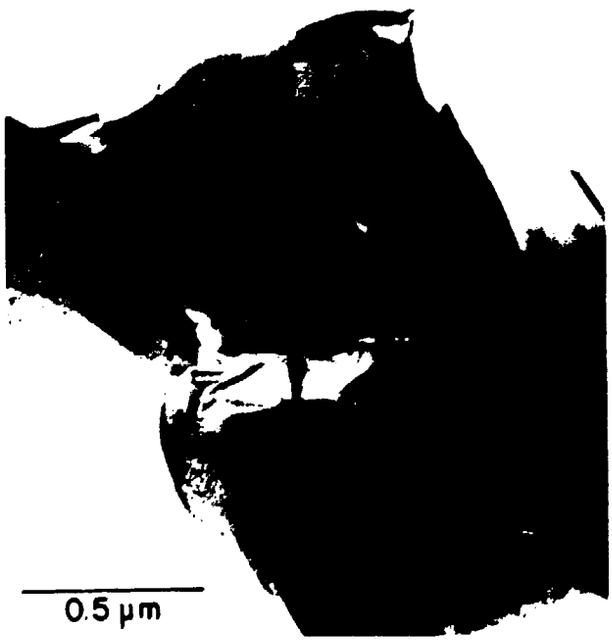

Fig. 3.36. Wyoming-type montmorillonite aggregates in the top layer Parys bentonite (sample 51) from South Africa.

Fig. 3.37. A typical mica flake with its SAD pattern in sample 51 from Parys, South Africa.

type aggregates make up about 50% of the smectite particles. Such an aggregate is shown in Fig. 3.36. Mica flakes are the common impurities in all the above samples, and Fig. 3.37 shows a typical mica with its SAD pattern from sample 51. In the middle and bottom layer of Parys bentonite (samples 52 and 53), smectite particles occur mostly as S-type lamellae and as compact lamellar or foliated aggregates.

In the bentonite from Plettensberg Bay (sample 54), Wyoming-type aggregates and H-type lamellae are the common forms of smectites. After the dispersion treatment, these aggregates break down into a large number of S-type lamellae.

Mozambique (Portuguese East Africa)

There is an interesting occurrence of bentonite adjacent to the main highway about 25 miles east of Laurenco Marques (Fig. 3.38). Here glassy perlitic lava of the Stormberg Series of the Karoo System of Liassic age has been altered irregularly by deuteric actior to bentonite. In this deposit, the alteration has produced masses of bentonite tens of feet thick. The bentonite varies from relatively pure montmorillonite (sample 55) to material contain-

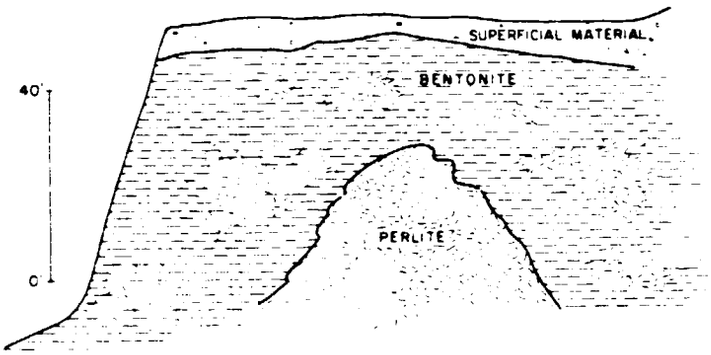

Fig. 3.38. Sketch of bentonite occurrence in perlite, Laurenco Marques, Mozambique (sample 57).

ing variable but considerable amounts of cristobalite and fine particles of unaltered rhyolite (samples 56 and 57). These latter materials are at places disseminated through the clay, whereas at other places they are present in substantial masses containing disseminated montmorillonite. The concentrations of the montmorillonite are not related to any series of fractures in the rhyolite, which would suggest hydrothermal alteration beginning along such fractures. Rather, the masses of bentonite are isolated and randomly distributed in the rhyolite, indicating that the alteration process developed within the rhyolite. The bentonite is the calcium variety. It has been extensively developed commercially.

The perlitic beds of the Stormberg Series continue to the south in Zululand of the Natal Province, Union of South Africa (p. 67). As for the Natal bentonite, deuteric processes are believed to have been the mode of origin of these Mozambique deposits.

In the northern part of Mozambique there is a large basin of Cretaceous and Tertiary sediments. There appears to be no record of bentonite in this area, but based on the common occurrence of bentonite in rocks of this age, its presence is likely.

Mineralogical studies on Mozambique bentonites. The X-ray diffraction data on the three samples in Table 3.3A indicate that they all contain a Na-montmorillonite with a basal spacing between 12.3—12.6 Å. These are samples which have been processed with the addition of soda ash. Tridymite or cristobalite is a major component in these samples. The free silica (tridymite, cristobalite) content of the samples 55 and 57 is as high as about 60%, which accounts for the low amount of total extractable cations. The appreciable amounts of magnesium among the extractable cations for samples 55 and 57 must be related to some other minerals than the mont-

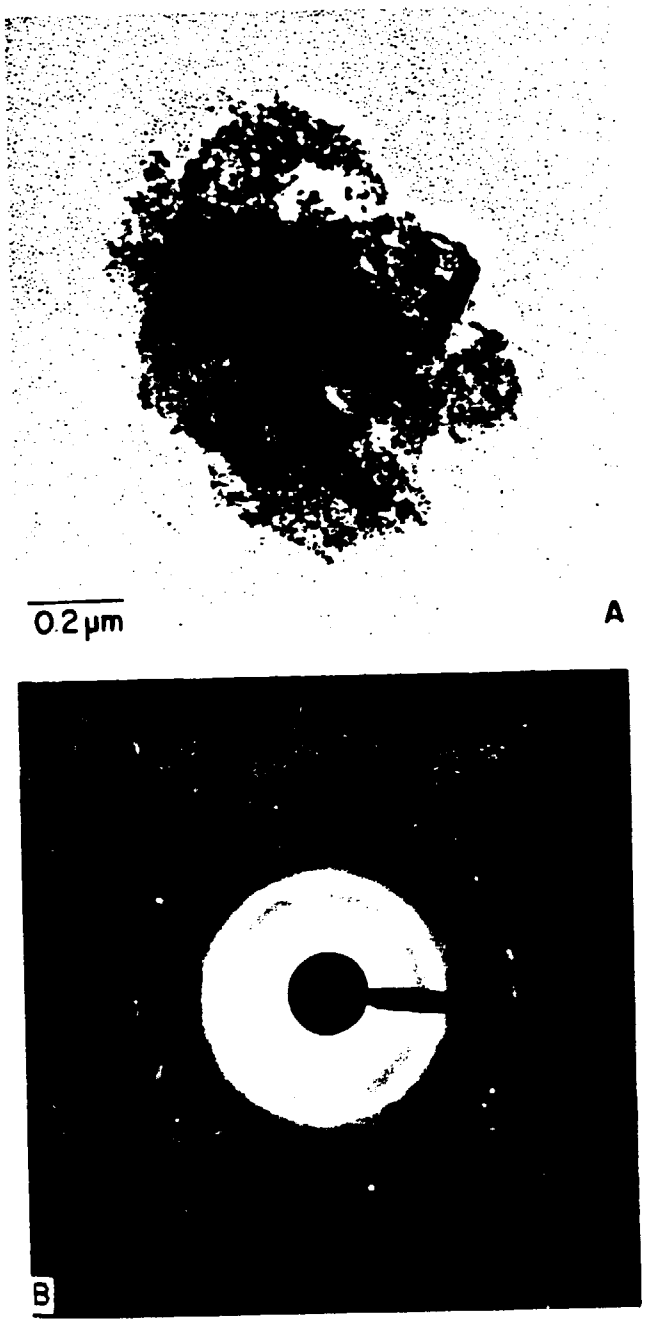

Fig. 3.39. A. Fine granular aggregate consisting of tridymite and montmorillonite. B. Its SAD pattern displaying two diffraction rings for these minerals. (Sample 55, Mozambique.)

morillonite. Tridymite occurs in fine granular aggregates as shown in Fig. 3.39A. The aggregate also contains smectite as revealed by the 4.45 and 4.11 Å rings in the SAD pattern of the aggregate (Fig. 3.39B). The 4.11 Å spacing suggests that the silica phase consists of tridymite.

Smectite particles occur mostly in the form of Wyoming-type aggregates in samples 55 and 57. In these samples, laths formed by back folding of smectite lamellae are occasionally observed. The perlite bentonite (sample 56) contains appreciable amounts of montmorillonite—cristobalite aggregates similar to those described above. In addition, H-type particles and Wyoming-type aggregates are the common forms of smectites.

Egypt

Information concerning possible bentonites in Egypt is very scant. Gindy and Badra (1968) have described clays which appear to be bentonites from the northwestern desert region. The clays occur alternating with marine carbonate beds in the lower and middle members of Middle Miocene formations. The authors also report montmorillonite marls interbedded with gypsum deposits in Pleistocene lagoonal deposits between fossil coastal bars of the Mediterranean Sea west of Alexandria. The origin of these clays and marls may be related to weathering or alteration of volcanic ash, but this cannot be established definitely. Basta et al. (1971) have recently reported bentonite from Faiyum.

Kenya and Tanganyika

Analyses of several samples of clay from the Rift Valley of Kenya and Tanganyika supplied by the Geological Survey of Kenya indicate that a smectite is the dominant clay mineral. The samples are Tertiary to Recent in age, but no specific information is available regarding occurrence, associated beds, etc. The occurrence of bentonite is not surprising in view of the presence of volcanics in the area.

Shackleton (1946) has reported bentonites between Nanyuki and Maralal in Kenya. Bentonite is also reported in the Athi River and Timau areas by Du Bois and Walsh (1971).

Sudan Republic

Whiteman (1971) reports the presence of bentonitic clays in a Mesozoic section encountered in a bore hole for the foundation of a bridge across the Nile River at Shambat.

Southwest Africa

Bentonites are known in several areas in Southwest Africa, but no specific information concerning them could be obtained.

References

Algeria and Morocco

Anonymous, 1973. Bentonite in Europe. Ind. Miner. (London), 64: 9—20.

DeLapparent, J., 1937. Origin of bentonites from North Africa. C. R. Soc. Geol. Fr., 10: 126—128.

DeLapparent, J., 1945. Deposits of the smectitic clays in North Africa. C. R., 221 (13): 335—337.

Frey, R., Yovanovich, B. and Burghelle, J., 1936. Composition and probable genesis of some decolorizing clays of North Africa. Serv. Min. and Carte Geol. Morocco, Mem., 38: 65 pp.

Grim, R.E. and Kulbicki, G., 1961. Montmorillonite: high temperature reaction and classification. Am. Mineral., 46: 1329—1369.

Sadran, G., Millot, G. and Bonifas, M., 1955. The origin of bentonite deposits at Lalla Maghnia (Oran). Serv. Carte Geol., Algeria, Bull., 5: 213—234.

Termier, H., Termier, G. and Korenko, V., 1956. On the occurrence of bentonite of Miocene age between Menerville and Dra-el-Mizane, Algeria. Serv. Carte Geol., Algeria, B.n.s., 8: 291—301.

Egypt

Basta, E.Z., El-Kadi, M.B. and Maksoud, M.A., 1971. Mineralogy of some bentonitic clays from Faiyum. Cairo Univ. Fac. Sci., Bull., 43: 271—284.

Gindy, A.R. and Badra, A., 1968. Bentonite-like clays and marls in the northwestern desert of Egypt. Proc. Egypt. Acad. Sci., 21: 11—36.

Kenya and Tanganyika

DuBois, C.O.D. and Walsh, J., 1971. Minerals of Kenya. Geol. Surv. Kenya, Bull., 11: 1—82.

Shackleton, R.M., 1946. Geology of the country between Nanyuki and Maralal. Geol. Survey Kenya, Rep., 11: 54 pp.

Sudan Republic

Whiteman, S.J., 1971. Geology of the Sudan Republic. Clarendon Press, Oxford, 291 pp.

Mozambique

Tavares, A.F., 1973. Bentonitas nos Limbobas. Men. Inst. Invest. Cient. Moçambique, Ser. b, 9: 1—15.

3.4. BENTONITES IN EUROPEAN AND EASTERN MEDITERRANEAN COUNTRIES

Bentonites are well known and have been extensively studied in many countries of Europe. Important producers of bentonite are located in England, Spain, Germany, Hungary, Poland, Romania, Czechoslovakia, Yugoslavia, Italy, Greece, and Bulgaria.

Austria

The Tertiary formations, particularly of Lower and Middle Miocene age, of Austria contain volcanic ash and tuff which in some places has altered

enough material to both satisfy the domestic market and also make the country a significant exporter of EMD

New bentonite deposit

The recent discovery of a large sodium-magnesium bentonite deposit 300km east of Cape Town has been announced. The quantity of material discovered has been put in excess of a 'few' million tonnes, although since exploration is still continuing it is difficult to make an accurate measurement of actual reserves. As far as quality is concerned it is claimed that the bentonite is comparable, if not better than that of Wyoming bentonite. The production of the sodium magnesium bentonite began a few months ago for the local market and export possibilities are now being investigated. The bentonite is called 'Swellenite' and is produced by Cape Bentonite (Pty) Ltd. of Heidelberg. The world marketing rights are held by Metallgesellschaft SA (Pty) Ltd., a subsidiary of Metallgesellschaft AG of Frankfurt.

In the area worked by Cape Bentonite there are slight differences in quality. One area consists of a bentonite with a base exchange capacity of well over 100m.e./100 gr, an exceptionally high green strength and a medium dry strength. In another area a bentonite of a lower green strength but a higher dry strenth was discovered. Because of particularly small particle sizes the filter loss properties are low and thus, for example, are ideal for oilwell drilling purposes. In addition a nearly white bentonite with a low iron content can be mined which should be suitable for pharmaceutical purposes.

TAIWAN

Marble industry boom

Exports of marble from Taiwan in 1979 were worth $20m., an increase of nearly 25% on the previous year. Work is currently in hand to upgrade the quality of the finished marble products, since inadequate equipment means that Taiwan cannot compete with Italy despite possessing some varieties of marble of superior quality. Taiwanese marble is of similar geological age to that of Yunnan on the Chinese mainland and is about 350m. years old. On the basis of colour and pattern it can be divided into fifteen categories of which straight line, curved, reticulated, and clouded are the most common. The rarest is pure black, although green (serpentine) and fossil (light brown) are also not very common.

The main area of production is on the eastern side of Taiwan around Hualien. In Hualien county around 30,000 people are employed by the marble industry and the majority of these are involved with the production of decorative marble products, although there are around 80 factories producing building materials. The marble deposits extend out of Hualien county into Ilan and Tatung counties in the form of a long narrow vein of material that extend 20km from Suao in Ilan to Chihpen in Tantung. The maximum width of the vein is 10km and in places it reaches a depth of 1,000 metres. The Taiwan Mining Bureau has estimated that the deposits total some 300,000m. tons, spread over 42,500 ha.

UNITED KINGDOM

Detergents bright spot in H_2SO_4 consumption

According to figures released by the National Sulphuric Acid Association consumption of sulphuric acid in the UK during the 2nd quarter of 1980 totalled 936,091 tonnes, which represented a fall on both the previous quarter and the same period in 1979. The fall in consumption over the previous quarter was 1.9% and on the second quarter in 1979 was 4.7%. The downfall was not unexpected because of the current industrial recession and in fact was not as bad as some feared. It is also slightly misleading to compare the second quarter of this year with the second quarter figures of last year because in that period there was a lot of stock replenishment after the industrial unrest and bad weather conditions of the first quarter which produced an artificially high consumption figures (see IM Sept. 79). During the second quarter of this year decreases in consumption were reported by all but three industries. Particularly noticeable, however, were the falls in oil and petrol, chemicals, metal-

Consumption of sulphuric acid and oleum

Trade uses	*Metric tons 100% H_2SO_4*	*Percentage increase* decrease over 2nd qtr. 1979*
Fertilisers & Agricultural (incl. 245,901 metric tons for phosphatic fertilisers 25,250 metric tons for sulphate of ammonia	276,854	+ 1.5
Paints and pigments	133,169	– 6.9
Natural and man-made fibres and transparent cellulose film	75,109	– 14.1
Chemicals (incl. 25,434 metric tons for plastics 20,784 metric tons for sulphates of alumina, barium, copper, magnesium and zinc	137,691	– 21.1
Detergents and soaps	140,165	+23.3
Metallurgy (incl. 13,084 metric tons for steel pickling)	15,275	– 17.8
Dyestuffs and intermediates	18,254	+ 6.3
Oil and petrol	5,755	– 22.1
Miscellaneous uses (incl. 58,378 metric tons for exports)	133,819	– 9.2
Total	*936,091	– 4.7

**Includes 8,434 metric tons of imported acid and 18,284 metric tons of recovered acid.*

-5

BENTONITE

Minerals Yearbook
Volume III
Area reports: International
US Department of the interior, Bureau of mines

Statistical supplement 1982 to the economics of bentonite, fuller's earth and allied clays; third edition 1979.
Roskill info service. London january 1982, 49 p.

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0601012 GA516000224
Clays bentonite (Production 4/6/79, 4/6/78)
Minerals (Pretoria) 79/2 P26-27 1979 JRNL CODE: MINEPI
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DESCRIPTORS: MINERAL PRODUCTION STATISTICS; BENTONITE DEPOSITS
AUXILIARY DESCRIPTORS: SOUTH AFRICA
DESCRIPTOR CODES: 353800; 456600
AUXILIARY DESCRIPTOR CODES: 670000

0800013 GA724000737
The bentonitic clays
HABBURRUMMAN, S
Arab Min J (Amman) 4/4 P67-69 1984 JRNL CODE: AMJOAG
LANGUAGE: ENGLISH
DESCRIPTORS: BENTONITE DEPOSITS: SMECTITE GROUP
AUXILIARY DESCRIPTORS: ALGERIA; MOROCCO
DESCRIPTOR CODES: 456600; 527300
AUXILIARY DESCRIPTOR CODES: 614000; 617000

6/5/5
0566051 GA480000964
Exploitation of the mineral wealth of Lake Qarun (bentonite and brine e, Egypt)
ESTEFAN, SF
Chem Ind (London) 16 P535-536 1979 JRNL CODE: CINDUI
LANGUAGE: ENGLISH
DESCRIPTORS: PRODUCTION MANAGEMENT; BENTONITE DEPOSITS; SALT LAKES
AUXILIARY DESCRIPTORS: WESTERN DESERT
DESCRIPTOR CODES: 353000; 456600; 498200
AUXILIARY DESCRIPTOR CODES: 611500

6/5/4
0710203 GA619000319
Clarification of the genesis of a bentonite deposit of Bou-Hadua (Nador region)
MALECHA, A
Mines Geol Energ (Rabat) 46 P201-202 1979 JRNL CODE: MGENRI
LANGUAGE: FRENCH
DESCRIPTORS: BENTONITE DEPOSITS; ORE GENESIS
AUXILIARY DESCRIPTORS: NADOR
DESCRIPTOR CODES: 456600; 415000
AUXILIARY DESCRIPTOR CODES: 617490

6/5/3
0610986 GA526000078
South Africa new bentonite deposit
Ind Miner (London) 156 P15 1980 JRNL CODE: IMINLI
LANGUAGE: ENGLISH
DESCRIPTORS: MINERAL DISCOVERIES; BENTONITE DEPOSITS
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MINES GEOL. ENERG.; 0251-4079; MAR; Date: 1981; No: 49; p.: 102-137; 10 REF.; Loc: BRGM/MA7; Analyses: *9; Tables: 7; Illustrations: TABL.; Cote: 4416; Langue: Francais Type: TP, LA
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815588 76-41834

Die Bodenschaetze im Suedwesten Madagaskars
Mineral resources in southwestern Madagascar
Hedrich, M. J.
Glueckauf 112: 35, 220-224p., 1976
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Subfile: B

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Section Headings: 26 .(ECONOMIC GEOLOGY, GENERAL & MINING)

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BRIGHT FUTURE FOR NEGLECTED MINERALS
Anon
S Afr Min Eng J v 88 n 4110 Nov 1975 p 28-29, 31 Coden: SMIJA

The main products Zimro produces from its own mines, all open-cast, are: Andalusite-from 50 000 to 60 000 t a month obtained by an earthmoving operation at Burgersfort. Andalusite, a high-alumina material used in refractories and the ceramics industry, is important because of its resistance to high temperatures. Bentonite-mined at Parys in a 30 000 t a year operation. This clay has the quality that its molecules expand but remain attracted to each other when it is dissolved in water, thus forming a jelly. It is used in foundries, oil drilling, construction, dam sealing and other industries. Kaolin-from a 12 000 t a year operation at Grahamstown, is used in the board, paper, ceramics and paint industries. Limestone-from a 12 000 t a year operation near Mafeking, Zimro's limestone goes into the manufacture of resin and oil putties. Industrial talc, taken from a small 4 000 t-a-year operation at Piet Retief. There are no known deposits of cosmetic talc in South Africa. Talc is used largely in pesticides and ceramics

Card-A-Lert Codes: 501 (Mine and Quarry Equipment and Operations) / 505 (Mines and Mining, Nonmetallic) /
Controlled Terms: *MINES AND MINING /

Mineralogy of some bentonitic clays from Faiyum, U.A.R. and Aldress, Shropshire, England
Basta, E. Z.; El-Kadi, M. B.; Maksoud, M. Abdel.
Cairo Univ., Fac. Sci., Bull. No. 43 (1970), p. 271-284, illus., 1971
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Subfile: B
Doc Type: SERIAL
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Surowce mineralne Mozambiku
Mineral resources of Mozambique
Smakowski, Tadeusz.
Przegl. Geol. Vol. 22, No. 11, p. 564-566, sketch map, 1974
CODEN: PRZGAL
Subfile: B
Doc Type: SERIAL
Languages: Polish
Descriptors: *Mozambique; *Mineral resources ; Economic geology; Africa ; coal; gas; natural; iron; titanium; manganese; copper; gold; bauxite; uranium; fluorspar; bentonite; reserves; production; economics
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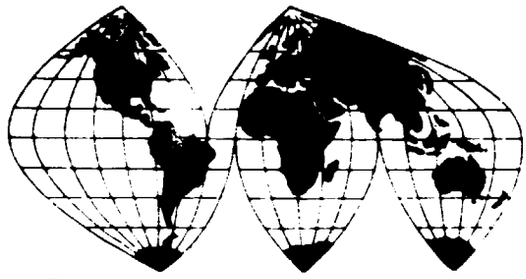

Industrial Minerals *16 yr* Index

Edited by G.M. Clarke

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FOREWORD

This edition of the *Industrial Minerals Index* not only spans the first 16 years of the journal from October 1967 to September 1983 but also incorporates a number of additions and modifications since the publication of the last Index in July 1981. A brief glance through the pages of *Industrial Minerals* journal and its associated publications is enough to demonstrate the breadth of scope of this comparatively quiet sector of the extractive mineral industries. As a result, time and again the reader is faced with the question of when a particular mineral, country, consuming industry, takeover, new venture, etc. was covered in the journal. Hence the need for this new improved edition of the *Industrial Minerals Index*.

For the first time since its inception in December 1977, the regular column, *Fillers and Extenders*, has been indexed. For nearly six years this column has served the dual purpose of highlighting the unusual and lighter side of industrial mineral's related events as well as providing the facility for incorporating "late" items of important new developments. For the purpose of indexing, each item in *Fillers and Extenders* has been given a headline and more recent issues of the journal now incorporate headlines in this column. In this way many important items of news are now firmly on the record.

The new Index includes a major section which covers articles and news items focussing on the principal mineral consuming industries. For many reasons this is perhaps a highly contentious area but, for the purposes of indexing, ease of reference is the priority. As such the generic categories of fertilisers and refractories are now included in the consuming industries' section, although the intermediate nature of the products and the high degree of vertical integration of many companies involved in these fields, often lead to the manufactured product being the dominant factor in the industrial marketplace rather than the mineral. Similarly titanium dioxide pigments have now been incorporated in this section as they represent manufactured products destined for a specific end use, although in diverse market sectors. Where a mineral has a synthetic, chemically manufactured analogue serving similar or overlapping markets it has been included in the mineral section eg. soda ash and magnesite.

In 1974 *Industrial Minerals* launched the first in its series of *International Congresses* in London, and has since taken the event to Munich, Paris, Atlanta, and Madrid in alternate years. Details of the many papers published in the congress proceedings are now included in this Index with cross references to the relevent categories. Similarly articles and papers published in *Industrial Minerals'* special surveys, supplements, and other conference proceedings are also included.

In searching this Index for a particular subject the user is reminded to refer to all sections. In order not to overburden the Index, excessive cross references have been avoided. Much useful information on a given mineral topic is not only to be found in the core mineral-by-mineral section but also in the other sections on countries, consuming industries etc. as well as in the regular feature of Comment, and Fillers and Extenders. Finally within *Industrial Minerals* journal the Index is updated every six months in the January and July issues.

G.M. Clarke – Editor

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Barytes: raw materials for fillers and extenders, by E. Sibbing (IM5 London, page 150, 1974)
Technology and uses of barium and strontium compounds, by J Massonne (IM5 Madrid, page 115, 1982)

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A new source of salt-water clay in Turkey, by Y.Turan (IM1 London, page 206, 1974)
Bentonite – a valuable and versatile mineral and raw material, by C.E.Hofstadt and R.Fahn (IM2 Munich, page 95, 1976)
European and Mediterranean bentonite markets and processing developments, by A.Piras and G.Novelli (IM3 Paris, page 55, 1978)
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Britain's industrial minerals: their geological framework, their production today, and some aspects of their development, by A.W.Woodland and D.E.Highley (IM1 London, page 2, 1974)
Industrial minerals mining in **Turkey**, by F.Karayazici (IM1 London, page 196, 1974)
New Brunswick evaporites in an economic context, by D.W.Davis (IM1 London, page 229, 1974)
Finland's industrial minerals and their growing markets, by R. Seiktonen (IM1 London, page 229, 1974)
The industrial minerals of the **Federal Republic of Germany** and the role of the industry in the public scene, by G. Luttig et al (IM2 Munich, page 3, 1976)
Industrial minerals in **Newfoundland** and **Labrador**: Export potential and internal industrial growth, by J.M.Fleming and J.G.McArthur (IM2 Munich, page 17, 1976)
The industrial minerals of **Sardinia**: Present situation and future perspectives, by M.Carta et al (IM2 Munich, page 41, 1976)
Current activity and development prospects in the commercialisation of **Yugoslavia**'s industrial mineral resources, by M.Jelic et al (IM2 Munich, page 57, 1976)
The industrial minerals of **France**, by G.Berthoumieux (IM3 Paris, page 15, 1978)
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Our reference

16 August 1985

Dear Borje Hoglander

BENTONITE IN AFRICA

Thank you for your letter of 24 July. Data published in "Industrial Minerals" and attributed to us is taken from our annual publication "World Mineral Statistics. This publication is available at a cost of £20.00 from the National GeoScience Data Centre at the following address:

British Geological Survey
Keyworth
Nottingham NG12 5GG

Should you require further information on bentonite please contact Mr D Highley at the above address. We are obliged to make a charge for work undertaken for outside organisations. The rate for Mr Highley's time would be £203 per day.

I hope this is of assistance to you.

Yours sincerely

R N Crockett
Head, MISE Programme