Clay Minerals Soils to Engineering Technology to Cat Litter



USC Mineralogy Geol 215a (Anderson)

Clay Minerals

Clay minerals likely are the most utilized minerals ... not just as the soils that grow plants for foods and garment, but a great range of applications, including oil absorbants, iron casting, animal feeds, pottery, china, pharmaceuticals, drilling fluids, waste water treatment, food preparation, paint, and ... yes, cat litter!





Bentonite workings, WY

Clay Minerals

There are three main groups of clay minerals:



Kaolinite - also includes dickite and nacrite; formed by the decomposition of orthoclase feldspar (e.g. in granite); kaolin is the principal constituent in china clay.

Illite - also includes glauconite (a green clay sand) and are the commonest clay minerals; formed by the decomposition of some micas and feldspars; predominant in marine clays and shales.

Smectites or montmorillonites - also includes bentonite and vermiculite; formed by the alteration of mafic igneous rocks rich in Ca and Mg; weak linkage by cations (e.g. Na+, Ca++) results in high swelling/shrinking potential

Clay Minerals are Phyllosilicates



All have layers of Si tetrahedra



SEM view of clay



and layers of Al, Fe, Mg octahedra, similar to gibbsite or brucite

Clay Minerals



The kaolinite clays are 1:1 phyllosilicates



The montmorillonite and illite clays are 2:1 phyllosilicates

1:1 and 2:1 Clay Minerals



Marine Clays

Clays mostly form on land but are often transported to the oceans, covering vast regions.



Clay mineral distribution on the ocean floor, showing the dominant mineral in the <2 micron fraction. Mixture indicates that no one clay mineral exceeds 50% of the total.

Kaolinite Al₂Si₂O₅(OH)₂





Kaolinite clays have long been used in the ceramic industry, especially in fine porcelains, because they can be easily molded, have a fine texture, and are white when fired.

These clays are also used as a filler in making paper.

In the United States, deposits are found primarily in Georgia, North Carolina, and Pennsylvania; china clay is also mined in England (Cornwall) and France.



Kaolinite is the purest of clays, meaning that it varies little in composition. It also does not absorb water and does not expand when it comes in contact with water. Thus, kaolinite is the preferred type of clay for the ceramic industry. Kaolinite





Illite



changeable Cation nH₂O



Relict zircon in illite

Illite is similar to muscovite and is the most common clay mineral, often composing more than 50 percent of the claymineral suite in the deep sea.

They are characteristic of weathering in temperate climates or in high altitudes in the tropics, and typically reach the ocean via rivers and wind

transport.



Illite

The Illite clays have a structure similar to that of muscovite, but is typically deficient in alkalies, with less Al substitution for Si. Thus, the general formula for the illites is:

 $K_yAl_4(Si8_{-y},Al_y)O_{20}(OH)_4$, usually with 1 < y < 1.5, but always with y < 2.

Because of possible charge imbalance, Ca and Mg can also sometimes substitute for K.

The K, Ca, or Mg interlayer cations prevent the entrance of H2O into the structure. Thus, the illite clays are **non-expanding** clays.



Illite type clays are formed from weathering of K and Alrich rocks under high pH conditions. Thus, they form by alteration of minerals like muscovite and feldspar. Illite clays are the main constituent of shales.

Montmorillonite

Montmorillonite or smectite is family of expansible 2:1 phyllosilicate clays having permanent layer charge because of the isomorphous substitution in either the octahedral sheet (typically from the substitution of low charge species such as Mg²⁺ , Fe²⁺, or Mn²⁺ for Al³⁺)



Montmorillonite



The most common smectite is Montmorillinite, with a general chemical formula :

(1/2Ca,Na)(Al,Mg,Fe)₄(Si,Al)₈O₂₀(OH)₄.nH2O

Montmorillinite is the main constituent of <u>bentonite</u>, derived by weathering of volcanic ash. Montmorillinite can expand by several times its original volume when it comes in contact with water. This makes it useful as a drilling mud (to keep drill holes open), and to plug leaks in soil, rocks, and dams.

Montmorillinite, however, is a dangerous type of clay to encounter if it is found in tunnels or road cuts. Because of its expandable nature, it can lead to serious slope or wall failures.

SEM View of Montmorillonite



From Yucca Mountain, NV

Swelling Clays

The interlayer in montmorillonite or smectites is not only hydrated, but it is also expansible; that is, the separation between individual smectite sheets varies with the amount of water present in the soil. Because of this, they are often referred to as "**swelling clays**".

Soils having high concentrations of smectites can undergo as much as a 30% volume change due to wetting and drying or these soils have a high shrink/swell potential and upon drying will form deep cracks.





bentonite

Painted Desert, NM





Bentonite-bearing shales, such as in the Painted Desert, are derived from weathering of volcanic ash. The leaching of silica is responsible for preservation of petrified wood

Vermiculite

Vermiculite is a high-charge 2:1 phyllosilicate clay mineral. It is generally regarded as a weathering product of micas. Vermiculite is also hydrated and somewhat expansible though less so than smectite because of its relatively high charge.



Granular clay absorbents, such as vermiculite, have been used for over 75 years to clean up minor drips, spills and over sprays in factories and garages



Vermiculite





Vermiculite possesses the special property of expanding to between <u>six and twenty times</u> its original volume <u>when heated to</u> <u>approximately 1,000 degrees Celsius. This</u> <u>process, called exfoliation, liberates bound</u> <u>water from between the mica-like layers</u> of the mineral and literally expands the layers apart at right angles to the cleavage plane.

Vermiculite is used to loosen and aerate soil mixes. Mixed with soil, it improves water retention and fertilizer release, making it ideal for starting seeds. Also used as a medium for winter storage of bulbs and flower tubers.

Mining of Bentonite



Early Americans found bentonite vital to their lives. Pioneers found moistened bentonite to be an ideal lubricant for squeaky wagon wheels. The mixture was also used as a sealant for log cabin roofing. The Indians found bentonite useful as a soap.

Bentonite Mines - USA

During the Cretaceous, volcanoes in the Yellowstone area of Wyoming were subject to long periods of eruptions. Ash falling from these eruptions dropped into seas which covered much of Wyoming, forming a sediment as much as 50 feet deep. These sediments were slowly altered into the clay known as bentonite.

In these deposits are contained 70% of the world's known supply of western or sodium type bentonite.



Swelling Clay Mapping - USGS

Red = High swelling clay content Blue = Next high Brown = Minimum



mud cracks of clay



Swelling Clay Mapping - USGS

Red = High swelling clay content Blue = Next high Brown = Minimum





Uses of Clay

Of course, soils...flowers don't easily grow out of rocks!



Uses of Clay - Soils

... or do our many grain foods, such as wheat





Spheriodal Weathering, San Diego Co.





Corn, Cactus, and Flowers

all need proper soils



Uses of Clay - Oil & Water Drilling



Uses of Clay - Drilling Mud



Cooling and cleaning the drill



Drilling mud slurry



"Gushers" used to be common until the use of drilling mud was implemented

Bentonite and other clays are used in the drilling of oil and water wells. The clays are turned into mud, which seals the walls of the boreholes, lubricates the drill head and removes drill cuttings.

Drilling Fluid: Lifeblood of the Well

In 1900, while drilling an oil well in Spindletop, Texas, workers ran a herd of cattle through a pit filled with water. The mud that resulted, a viscous, muddy slurry of water and clay, was pumped into the borehole. Drilling fluids are still called mud, but engineers no longer rely only on water and clay. Instead, they carefully design compounds and mixtures to meet specific needs under various drilling conditions. Modern drilling fluids are truly the lifeblood of the well. Today's deep wells could not exist without them.



Oil Wells



These wells could never have been drilled without the role of clays as drilling mud, now augmented with such compounds as barite

Central Texas



Uses of Clay - Contaminant Removal

Clay slurrys have effectively been used to remove a range of comtaminants, including P and heavy metals, and overall water clarification.





Schematic of montmorillonite absorbing Zn

Uses of Clay

Filtering: Clays are used to decolorize, filter, and purify animal, mineral, and vegetable oils and greases due to their high absorbing properties.



Environmental Sealants: Bentonite is used to establish low permeability liners in landfills, sewage lagoons, water retention ponds, golf course ponds, and hazardous waste sites.



Uses of Clay

Pharmaceuticals/ Cosmetics:

Bentonite is used as a binder in tablet manufacturing and in diarrhea medications. Clays are used as thickeners in a wide variety of cosmetics including facial creams, lipsticks, shampoos and calamine lotion.

Pelletizing: Bentonite is used to bind tiny particles of iron ore, which are then formed into pellets for use as feed material for blast furnaces.

Paints: Finely ground clays are used in the paint industry to disperse pigment evenly throughout the paint. Without clays, it would be extremely difficult to evenly mix the paint base and color pigment.







Other Uses of Clay



clay pipes



clay pots





ceramic vase

Uses of Clay - Cat Litter

How a Simple Idea Improved the Quality of Life for Millions

In 1947, an enterprising young man named Edward Lowe assisted his neighbor with a problem she was having. The woman was using ashes in her cat box and the cat was tracking the ashes throughout the house. Mr. Lowe suggested she try the all-natural granular absorbent clay that he was selling to garage and machine shop owners for use in cleaning up minor oil spills and drips.

Both the owner and her pet loved the absorbent clay granules. The rest, as they say, is history. From these modest beginnings, the \$1.3 billion cat litter industry was born and pet ownership was changed forever.

Kitty Litter

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all Batmans fantasies were shaltered in an instant



