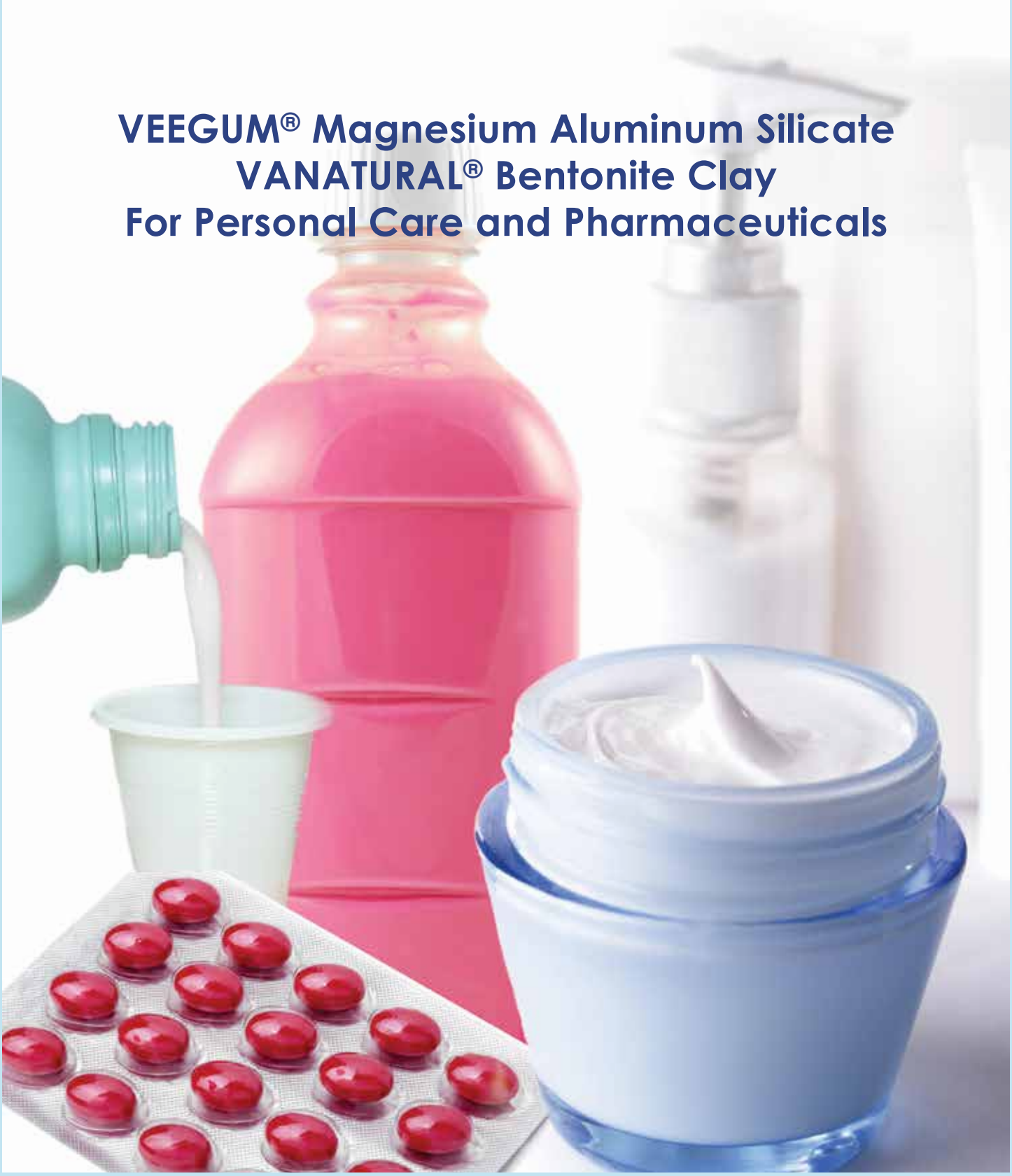
Vanderbilt Minerals, LLC

A Wholly Owned Subsidiary of R.T. Vanderbilt Holding Company, Inc.

# VEEGUM® Magnesium Aluminum Silicate
# VANATURAL® Bentonite Clay
# For Personal Care and Pharmaceuticals



Vanderbilt Minerals, LLC
A Wholly Owned Subsidiary of R.T. Vanderbilt Holding Company, Inc.

# TABLE OF CONTENTS

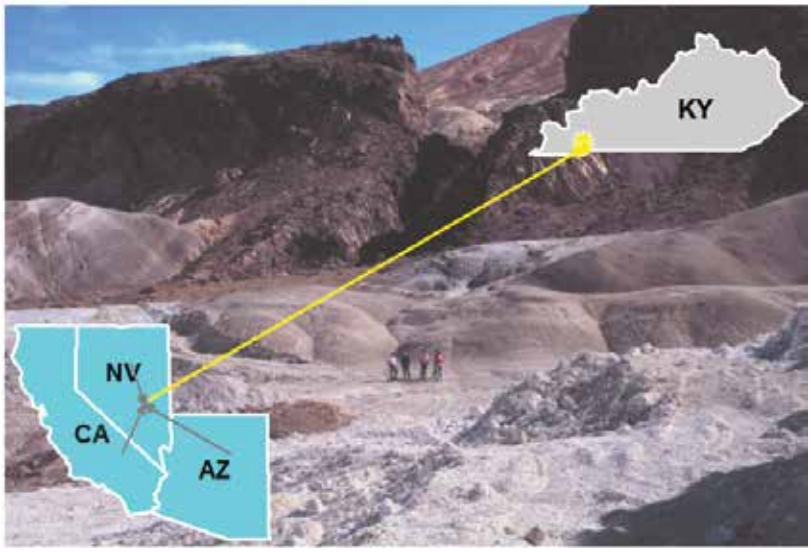



**Vanderbilt Minerals, LLC**
33 Winfield Street, P.O. Box 5150, Norwalk, CT 06856-5150
(800) 562-2476 Fax: (203) 855-1220
E-Mail: mineralsales@vanderbiltminerals.com
**vanderbiltminerals.com**

# VEEGUM® Magnesium Aluminum Silicate
# VANATURAL® Bentonite Clay
# for Personal Care and Pharmaceuticals

**VEEGUM** and **VANATURAL** products are natural smectite clays that have been water-washed to optimize purity and performance. Vanderbilt Minerals' diversified reserves in the U.S. southwest are the foundation of our clay's reputation for uniformity and quality. This secure resource base also enables the continuing development of new grades in response to customer needs.

The ores used to make **VEEGUM** and **VANATURAL** clays are mined in Nevada, Arizona and California. They are milled in Nevada and shipped to the clay processing plant in Murray, KY.




**VEEGUM** products are offered primarily for pharmaceutical and personal care applications, although they are widely used in other areas as well. **VANATURAL** products are designed for personal care applications, particularly those that require OMRI™, ECOCERT Greenlife™ or COSMOS™ (COSMetic Organic Standard™) listing as ingredients. All grades of **VEEGUM** and **VANATURAL** clays undergo the same water-washing process and meet the same standard of clay purity.

**VEEGUM® (left) preventing emulsion separation and creaming.**

**VEEGUM® (left) preventing pigment settling.**

## FORMULATION BENEFITS

**VEEGUM®** Magnesium Aluminum Silicate and **VANATURAL®** Bentonite Clay are valued by formulators of personal care and pharmaceutical products for their ability to:

- **Stabilize Emulsions** – One of the most useful features of these natural clays is their ability to stabilize oil-in-water (O/W) emulsions at low concentrations. The smectite colloidal structure effectively keeps the internal phase droplets suspended and separated. Since this structure is not affected by heat, these clays reduce the tendency of emulsions to thin out and break at elevated temperatures. Small amounts – typically 1-2% – will stabilize emulsions containing anionic or nonionic surfactants and a wide variety of oils, fats, and waxes. These clays are also effective in fluid water-in-oil (W/O) emulsions that are otherwise difficult to stabilize; they inhibit coalescence by increasing internal phase viscosity and by strengthening the interfacial water/oil film.

- **Stabilize Suspensions** – Like its emulsion stabilizing property, the colloidal structure of these natural clays provides excellent suspension of fine particles in aqueous systems. These clays:

    - Suspend even high density particulates
    - Prevent hard packing; suspensions that tend to settle are easily redispersed
    - Ensure pharmaceutical suspensions of uniform dosage
    - Achieve maximum suspension without losing pourability
    - Do not form gelatinous, irreversible gels, as do many organic gums
    - Offer better suspension efficiency than most organic gums at equal viscosity

- **Stabilize Organic and Natural Formulations** – **VANATURAL** and **VEEGUM Pure** clays are listed by the Organic Materials Review Institute (OMRI™). **VANATURAL**, **VANATURAL XGB** and **VEEGUM Pure** clays are authorized by ECOCERT Greenlife™ as complying with the ECOCERT™ and COSMOS™ standards for ecological and organic cosmetics.

- **Modify Rheology** – Shear-thinning products with controlled thixotropy can be formulated. Rich emulsions spread smoothly. Suspensions and emulsions freely pump or pour without losing stability.

- **Enhance Skin Feel** – **VEEGUM**® Magnesium Aluminum Silicate and **VANATURAL**® Bentonite Clay contribute spreadability and cosmetic elegance to topical products. Because of their insoluble, platy nature they are used to formulate tack-free topical products and to reduce or eliminate the tacky, gummy or stringy nature of organic gums and polymers.

- **Modify Organic Thickeners** – In addition to their tactile benefits, **VEEGUM** and **VANATURAL** clays are often used with organic thickeners to enhance the best characteristics of each. The clays contribute synergistic viscosity and yield value. Gums and polymers provide a protective colloidal action that improves the clay's stability in the presence of electrolytes, surfactants, and other water solubles. Recommendations for the use of these clays with organic thickeners are detailed in the section "Synergy With Organic Polymers and Gums."

- **Perform at High and Low pH** – **VEEGUM** and **VANATURAL** clays are routinely used in products spanning the pH 2 to pH 13 range. These include AHA emulsions, antiperspirants, antacids and internal analgesic suspensions. Certain grades are particularly effective at pH extremes, where their pH stability is further extended by protective colloids such as xanthan gum.

- **Function with Most Additives** – As anionic clays, **VEEGUM** and **VANATURAL** clays are compatible with most anionics and nonionics; they are incompatible with most cationics.

- **Resist Degradation** – Because they are minerals, **VEEGUM** and **VANATURAL** clays are not decomposed by bacteria, heat or excess mechanical shear.

- **Act as Binders and Disintegrants** – **VEEGUM®** Magnesium Aluminum Silicate and **VANATURAL®** Bentonite Clay are used as non-migratory binders in tablets, sticks, and pressed cakes. They do not migrate to the product surface during drying, thereby ensuring uniformity and the desired level of hardness, rub-off, and color value. They also function as low-bulk disintegrants in massive tablets where the active ingredient makes up the major weight and bulk of the composition.

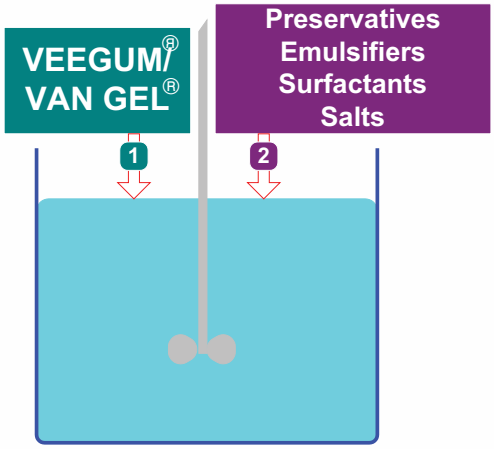
- **Provide Particular Functionality in Pharmaceuticals** – **VEEGUM** clays are used to modify drug release from solid dosage forms, ointments and suppositories, mask the taste of bitter drugs, and function as binders and in wet granulated and direct compression tablets.

# PREPARATION of DISPERSIONS

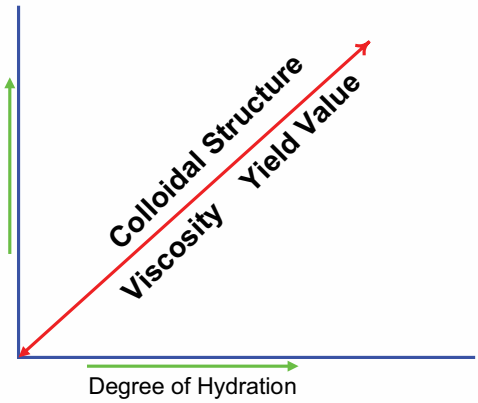
For emulsion stabilization, suspension stabilization and thickening, **VEEGUM**® Magnesium Aluminum Silicate and **VANATURAL**® Bentonite Clay must be properly dispersed in water and hydrated to provide the desired performance properties. The two guides to successful hydration are:

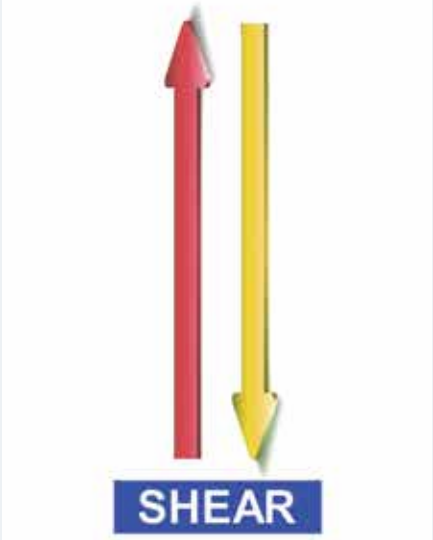
- √ **THE BEST DISPERSIONS ARE PREPARED IN WATER FREE OF ADDITIVES.**
- √ **MORE ENERGY INPUT GIVES QUICKER HYDRATION.**

Any materials present in the water when the clay is added, including preservatives, chelating agents or other minor additives, will interfere with hydration and inhibit the formation of the desired colloidal structure.




Dry clay particles are actually multiple layers of individual platelets, each separated by a layer of water. The extent to which these particles are delaminated into individual clay platelets is referred to as the degree of hydration. The greater the degree of hydration, the stronger the colloidal structure, and the greater the viscosity and yield value of the dispersion.



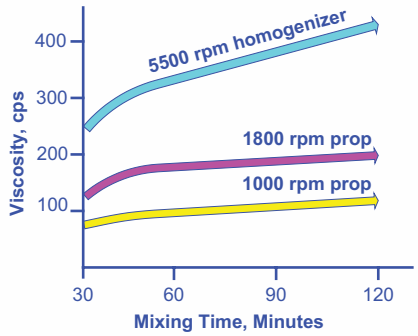





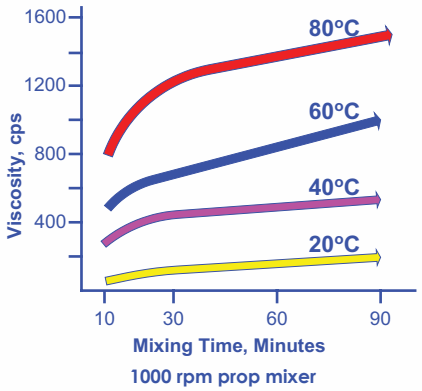

For most clay grades the degree of hydration is directly proportional to the amount of energy used to disperse the product, and therefore increases in proportion to the following factors:

- **Shear, or mixing intensity**
- **Heat input, or water temperature**
- **Mixing time**

Using greater shear, or mixing for a longer time, will provide better hydration, which is measured as higher viscosity, as seen here with a 5% dispersion of **VEEGUM**® Magnesium Aluminum Silicate , and greater yield value.




Heat input in the form of heated water has an even more pronounced beneficial effect on hydration than does the mechanical energy contribution of shear.



Any modification of mixer intensity (e.g., speed, propeller to vessel ratio) or water temperature will affect the degree of hydration and the hydration time. Whichever mixing conditions are used, it is very important that they be consistently controlled to achieve reproducible results in the laboratory, during scale-up and in production.

Because of their unique nature, **VEEGUM® Ultra** Magnesium Aluminum Silicate and **VANATURAL® XGB** Bentonite Clay are an exception. They are relatively unaffected by changes in hydration parameters. Adequate hydration will be achieved in most cases in no more than 15 minutes. Increasing mixing intensity, mixing time or water temperature will not significantly affect degree of hydration.

The following table provides guidelines for the minimum amounts of time suggested for the hydration of the various clay grades. They are based on laboratory scale preparations:

- 1 kg batches using distilled, deionized water at specification concentrations under practical formulating conditions.
- Actual hydration times in the laboratory or in production will depend on the particular combination of batch size, mixer shear, and water temperature used.
- In the laboratory or during production, the key to consistent performance of these clays is consistent hydration conditions.
- Changes in hydration time, mixer shear, vessel size or water temperature will change results.

# Minimum Suggested Hydration Times for VEEGUM® Magnesium Aluminum Silicate and VANATURAL® Bentonite Clay

## Hydration Rate

| | Normal | Fast | Ultra |
|---|---|---|---|
| | **VEEGUM®**<br>**VEEGUM K**<br>**VEEGUM HV**<br>**VEEGUM PURE**<br>**VEEGUM CH** | **VEEGUM HS**<br>**VEEGUM D**<br>**VANATURAL**<br>**VANATURAL MC** | **VEEGUM *Ultra***<br>**VANATURAL XGB** |
| **Propeller Mixer:** | | | |
| 800 rpm, 25°C water | 120 Minutes | 30 Minutes | 15 Minutes |
| 800 rpm, 75°C water | 45 Minutes | 20 Minutes | 10 Minutes |
| **Homogenizer:** | | | |
| 3000 rpm, 25°C water | 30 Minutes | 20 Minutes | 10 Minutes |
| 3000 rpm, 75°C water | 15 Minutes | 10 Minutes | 10 Minutes |

## SYNERGY WITH ORGANIC GUMS AND POLYMERS

**VEEGUM®** Magnesium Aluminum Silicate and **VANATURAL®** Bentonite Clay are often used synergistically with gums and organic thickeners. The viscosity or stability of formulations containing these mixtures will be greater than that of the same formulation made with each individual component of the mixture. These combinations allow the formulator to fine-tune viscosity, yield value, and flow properties beyond what is possible with either the clay or organic thickener alone.

For example, **VEEGUM** clay is frequently used with natural gums or cellulosic thickeners to provide a balance of suspension stability and smooth flow properties in oral suspensions and dandruff shampoos. **VEEGUM** and **VANATURAL** clay together with polyacrylates are used to optimize the rheology and aesthetics of topical emulsions. **VEEGUM** and **VANATURAL** clay are combined with carboxymethylcellulose in liquid makeups.

Other advantages of combining **VEEGUM** and **VANATURAL** clays with an organic thickener are:

- The combination may be more economical than the use of either component alone.
- **VEEGUM** and **VANATURAL** clays can impart yield value to systems thickened with high efficiency organic polymers or gums.
- Because the colloidal structure of these clays is not sensitive to heat, it can compensate for the loss of viscosity at elevated temperatures common to many organic thickeners.
- **VEEGUM** and **VANATURAL** clays can reduce the tacky, gummy or stringy nature of organic thickener solutions.

Because of the benefits of such clay/thickener combinations, Vanderbilt Minerals offers a pre-blended product: **VANATURAL XGB** (Bentonite and Xanthan Gum).

The table below provides suggested weight-to-weight ratios of **VEEGUM®** and **VANATURAL®** clays that will produce beneficial synergistic effects. Mixing procedures to introduce the two ingredients into the formulation are also recommended.

## Suggested Starting Weight to Weight Ratio Ranges of **VEEGUM®** Magnesium Aluminum Silicate or **VANATURAL®** Bentonite Clay to Organic Thickener[1,2]

| Organic Thickener | Weight to Weight Ratio Range | Recommended Mixing Procedure |
|---|---|---|
| **Polyacrylates** | | |
| Polyacrylates | 5:1 to 1:1 | A |
| Carbomers | 10:1 to 1:1 | A;B[3] |
| **Cellulosics** | | |
| Sodium Carboxymethylcellulose | 10:1 to 1:1 | C |
| Hydroxyethyl Cellulose | 1:1 | A,D |
| Hydroxypropyl Cellulose | 1:1 | A,D |
| Hydroxypropylmethylcellulose | 1:1 | A,D |
| Methylcellulose | 1:1 | A,D |
| **Natural Gums** | | |
| Xanthan Gum | 10:1 to 1:1 | C |
| Sodium Carrageenan | 10:1 to 1:1 | C |
| Sodium Alginate | 2:1 to 1:1 | C |
| Hydroxypropyl Guar | 1:1 | A |
| Gum Arabic (Acacia) | 4:1 to 2:1 | C |
| Gum Tragacanth | 9:1 to 2:1 | C |

[1]For initial evaluations. Ratios are based on rheological studies in water, alone. Preferable or optimum ratios may be different in formulated products.

[2]Does not apply to **VANATURAL XGB** Bentonite Clay, which is already blended with a gum.

[3]When using **VEEGUM *Ultra***

## Recommended Mixing Procedures

**A.** Divide the available water and prepare the hydrated clay dispersion and the organic thickener solution separately. Slowly add the thickener solution to the clay dispersion with good agitation. Mix until uniform before adding other formula ingredients.

**B.** Add the **VEEGUM® *Ultra*** Magnesium Aluminum Silicate and carbomer simultaneously or as a dry blend to the available water. Hydrate thoroughly before adding other formula ingredients. The carbomer can be neutralized at any convenient point after hydration.

**C.** Add the clay and organic thickener simultaneously or as a dry blend to the available water. Hydrate thoroughly before adding other formula ingredients.

**D.** For nonionic cellulosics that are insoluble in hot water: hydrate the clay in hot water. Add the gum to the hot clay dispersion with good agitation. Cool the dispersion with continued agitation until the gum is completely dissolved.

## NATURAL SMECTITE CLAYS - A GRADE FOR EVERY USE

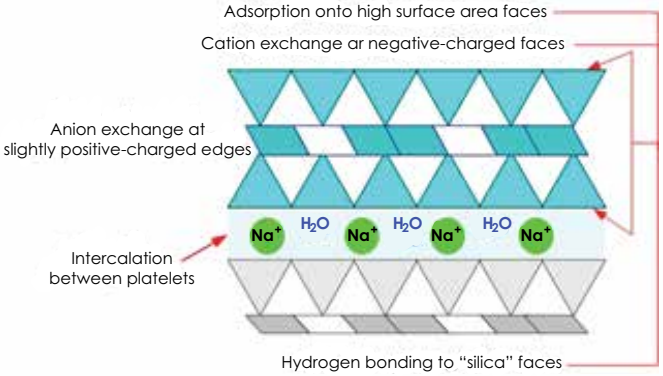
| | | |
|---|---|---|
| | **Pharmaceutical** | **Personal Care** |
| **VEEGUM® R** Magnesium Aluminum Silicate | X | X |
| **VEEGUM HV** | X | X |
| **VEEGUM K** | X | X |
| **VEEGUM HS** | X | X |
| **VEEGUM Pure** | X | X |
| **VEEGUM *Ultra*** | | X |
| **VEEGUM D** | | X |
| **VEEGUM CH** | | X |
| **VANATURAL®** Bentonite Clay | | X |
| **VANATURAL MC** | | X |
| **VANATURAL XGB** | | X |

## VEEGUM® Magnesium Aluminum Silicate Grades for Pharmaceuticals

**VEEGUM** clays have a long history of use as excipients in pharmaceutical formulations. In liquids, these clays are used primarily as suspension stabilizers and emulsion stabilizers. In ointments and suppositories they are used to control drug release. In solid dosage forms they are traditionally used as binders and disintegrants for wet granulations and, in micronized form, for direct compression tablets. These clays are also used in solid dosage forms as components of drug delivery systems, an application of increasing interest because these entirely natural excipients provide a unique combination of physicochemical properties for drug-clay interaction.

The structure of smectite clays allows for several routes to drug-clay interaction or complexation:

- Cation exchange with cationic drugs. This produces a relatively strong drug-clay bond on platelet faces that is suitable, for example, for extending drug release.
- Weak anion exchange of anionic drugs at platelet edges.
- Hydrogen bonding at platelet faces.
- Intercalation between un-delaminated platelets, which may be used for taste masking or for modifying drug release.
- Adsorption by solvent deposition onto the high surface area of the clay to increase the dissolution rate of poorly soluble drugs.




Although produced and certified to compendial specifications, these grades also have a long history of use in personal care, household, institutional, agricultural, and industrial formulations.

| | |
|---|---|
| **VEEGUM® R*** <br> Magnesium Aluminum Silicate | A useful, economical grade for a wide range of applications: pharmaceutical, cosmetic, personal care, veterinary, agricultural, household and industrial products. <br> Magnesium Aluminum Silicate NF Type IA <br> INCI Name: Magnesium Aluminum Silicate <br> Typical use levels: Between 0.5% and 3%. |
| **VEEGUM HV*** | Indicated where high viscosity at low solids is desired. Excellent emulsion and suspension stabilization is obtained at low use levels. It is used primarily in cosmetics (e.g., pigment suspension in mascaras and eye shadow creams) and pharmaceutical suspensions. <br> Magnesium Aluminum Silicate NF Type IC <br> INCI Name: Magnesium Aluminum Silicate <br> Typical use levels: Between 0.5% and 3%. |
| **VEEGUM K*** | Used in pharmaceutical oral suspensions at acid pH and in hair care formulas containing conditioning ingredients. It has low acid demand and high acid and electrolyte compatibility. It is used to provide good suspension at low viscosity. <br> Magnesium Aluminum Silicate NF Type IIA <br> INCI Name: Magnesium Aluminum Silicate <br> Typical use levels: Between 0.5% and 3%. |
| **VEEGUM HS** | For optimum pH stability in acidic pharmaceutical suspensions; maximum electrolyte stability and minimum acid demand. <br> Purified Bentonite NF <br> INCI Name: Magnesium Aluminum Silicate <br> Typical use levels: Between 1.0% and 3%. |

*Also available as Aluminium Magnesium Silicate EP grade

| APPLICATION GUIDE | | | | |
|---|---|---|---|---|
| **Pharmaceuticals** | **VEEGUM®** Magnesium Aluminum Silicate | | | |
| | **R** | **HV** | **K** | **HS** |
| API Creams and Lotions at pH > 6 | X | X | | |
| API Creams and Lotions at pH < 6 | | | X | X |
| API Suspensions at pH > 6 | X | X | | |
| Anti-dandruff, Treatment Shampoos | X | X | | |
| Tablet Binder/Disintegrant Wet Granulation | X | X | | |
| Tablet Release Regulator Rapid Release / Extended Release | X | X | | |
| Taste Masking | X | X | | |
| Dentifrices | X | X | | |

## VEEGUM® Magnesium Aluminum Silicate and VANATURAL® Bentonite Clay Grades for Personal Care

In addition to the pharmaceutical grades, these grades are used in personal care products. Although intended for personal care applications, **VEEGUM Pure** is produced to pharmaceutical grade specifications. Although not pharmaceutical grades, **VEEGUM *Ultra*** and **VEEGUM D** are used in certain OTC pharmaceuticals.

| | |
|---|---|
| **VEEGUM® *Ultra***<br>Magnesium Aluminum Silicate | A unique, fast hydrating acidic smectite clay for topicals. It is particularly useful in sunscreens and exfoliant acid emulsions.<br>INCI Name: Magnesium Aluminum Silicate<br>Typical use levels: Between 0.5% and 2% |
| **VANATURAL®**<br>Bentonite Clay | A water-washed bentonite clay listed with ECOCERT Greenlife™, COSMOS™ and OMRI™. A pure and natural suspension stabilizer, emulsion optimizer and rheology modifier for all topical products. It is particularly suited for creams, lotions, suspensions and other personal care products marketed as organic or natural.<br>INCI name: Bentonite<br>Typical use levels: Between 0.5% and 3% |
| **VANATURAL MC** | A pure and natural suspension stabilizer, emulsion optimizer and rheology modifier for all topical products. VANATURAL processed with strict control of microbiology for applications not requiring OMRI or ECOCERT listing.<br>INCI name: Bentonite<br>Typical use levels: Between 0.5% and 3% |

| | |
|---|---|
| **VANATURAL® XGB** | A tailored synergistic blend of high purity natural bentonite and xanthan gum that hydrates quickly, even with low shear mixing in unheated water. ECOCERT Greenlife™ and COSMOS™ listed. It imparts a pleasant application feel while reliably stabilizing water based suspensions and emulsions over a broad range of pH and storage temperatures. Especially recommended for difficult to stabilize suspensions and emulsions.<br>INCI name: Bentonite (and) Xanthan Gum<br>Typical use levels: Between 0.3% and 4% |
| **VEEGUM® Pure**<br>Magnesium Aluminum Silicate | This compendial conforming grade is ECOCERT Greenlife™, COSMOS™ and OMRI™-listed and the ideal emulsion stabilizer, suspension aid and thickener for organic and natural personal products.<br>Magnesium Aluminum Silicate NF Type IA<br>INCI Name: Magnesium Aluminum Silicate<br>Typical use levels: Between 1% and 3%. |
| **VEEGUM D** | A product designed for rapid hydration, even at high concentrations. It is used in dentifrice pastes and gels.<br>INCI Name: Magnesium Aluminum Silicate<br>Typical use levels: Between 0.5% and 3%. |
| **VEEGUM CH** | For use in high pH personal care compositions such as depilatory, waving and hair relaxer products.<br>INCI Name: Magnesium Aluminum Silicate<br>Typical use levels: Between 0.5% and 2%. |

| APPLICATION GUIDE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Personal Care**<br>**VEEGUM®** Magnesium Aluminum Silicate | | | | | | | | |
| | **VEEGUM** | | | | | | | |
| | **Ultra** | **R** | **Pure** | **HV** | **K** | **HS** | **CH** | **D** |
| Creams and Lotions at pH < 6 | X | | | | X | X | | |
| Creams and Lotions at pH > 6 | | X | X | X | | | X | |
| Sunscreens | X | X | X | X | | | X | |
| Antiperspirants | | | | X | | | | |
| Depilatories, Perms, Straighteners | | | | | | X | X | |
| Color Cosmetics | X | X | X | X | | | X | |
| Pressed Powder Color Cosmetics | | | | | | | X | |
| Loose Powder Color Cosmetics | | | | | | | X | |
| Dandruff Shampoos | | X | | | | | | |
| Conditioning 2-in-1 Shampoos | X | | | | | X | | |
| Facial Masks | X | | | | | X | X | |
| Dentifrices | | | | | | | X | X |

| APPLICATION GUIDE | | |
|---|---|---|
| **Personal Care**<br>**VANATURAL®** Bentonite Clay | | |
| | **VANATURAL/ VANATURAL MC** | **VANATURAL XGB** |
| Creams and Lotions at pH < 6 | | X |
| Creams and Lotions at pH > 6 | X | X |
| Sunscreens | X | X |
| Color Cosmetics | X | X |
| Facial Masks | X | |

# SMECTITE CLAYS

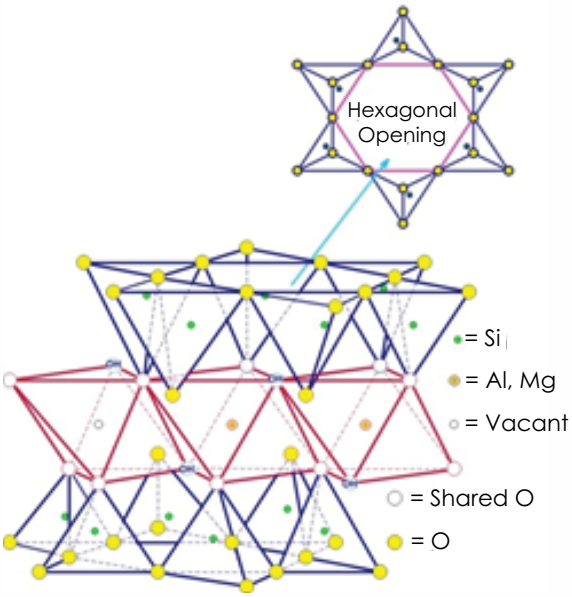
## VEEGUM® Magnesium Aluminum Silicate and VANATURAL® Bentonite Clay

### What They Are

Smectite is the mineralogical term for a group of trilayer clays which include the commercially significant varieties montmorillonite, hectorite and saponite. At one time this group was referred to generically as montmorillonite clay. The group name was changed to smectite clay to avoid confusion with the mineralogically distinct montmorillonite member, but the generic use of the term montmorillonite has persisted among some researchers. Smectite clays are also, by tradition, known under the geological term bentonite. Bentonite is an ore or product with substantial smectite content, most often montmorillonite.

Smectite clays have characteristic layered structures and consequently individual crystals have a flake or platelet shape. They contain a continuous alumina or magnesia octahedral layer that is bound on both sides by a continuous silica layer. The silica layer is composed of tetrahedra with three shared oxygens, forming linked rings with hexagonal openings. When the predominant octahedral cation is $Al^{3+}$, as in montmorillonite, charge balancing within the clay lattice requires that only two of every three octahedral positions are filled, and the clay is described as dioctahedral. If $Mg^{2+}$ predominates, as in saponite and hectorite, all octahedral positions must be filled, and the clay is called trioctahedral. A single smectite clay crystal is 0.96 nanometer thick and up to several hundred nanometers across.

The smectite clays are characterized by metal ion substitutions within their lattice structures, so that they are electrically unbalanced. Substitutions within the crystal lattice result in negatively charged platelet faces. Lattice discontinuities account for a very slight positive charge on edges. The net platelet charge is negative.

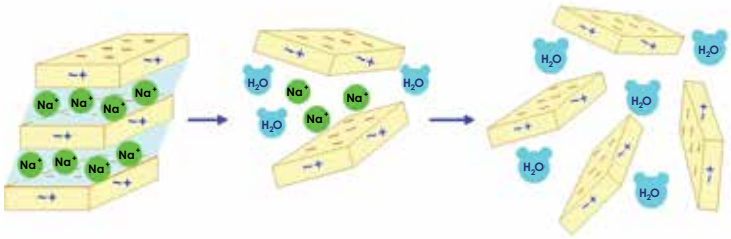



Montmorillonite is characterized by the substitution of a limited number of octahedral $Al^{3+}$ with $Mg^{2+}$, which accounts for its negative charge. This is naturally balanced by $Na^{+}$ between the clay platelets, partially sunk in the hexagonal openings of the silica layer. Because the sodium ions are not structural they can be easily replaced by other positively charged elements or molecules, and are called exchangeable cations. In addition to the charge balancing cations, a tightly held layer of oriented water, about 0.29 nanometers thick, occupies the space between individual flakes. This water requires temperatures well in excess of 100°C for removal. A single **VEEGUM**® Magnesium Aluminum Silicate or **VANATURAL**® Bentonite Clay particle is composed of thousands of these sandwiched platelets with exchangeable cations and a layer of water between each.

The trioctahedral analogues of montmorillonite are saponite and hectorite. Saponite has limited substitution of tetrahedral $Si^{4+}$ by $Al^{3+}$, while hectorite has limited substitution of octahedral $Mg^{2+}$ by $Li^{+}$ and $OH^{-}$ by $F^{-}$. As with montmorillonite, the resulting charge imbalance is naturally compensated for by exchangeable $Na^{+}$.

## Clay Hydration

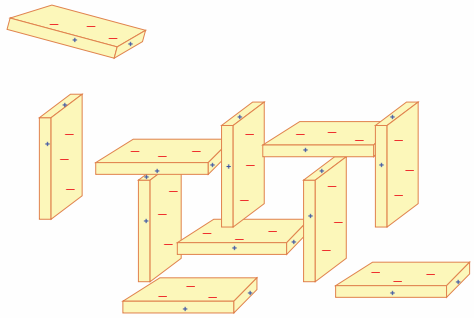
The binding effect of inter-platelet water and counterions makes mechanical delamination of smectite clays very difficult, but swelling by intercalation with polar liquids and solutions is quite easy. Likewise, in cases where the full surface area of the clay needs to be exposed and/or its rheological properties exploited, hydraulic delamination is relatively simple. When clay and water are mixed, water penetrates between platelets forcing them further apart. The cations begin to diffuse away from platelet faces. Diffusion (the movement of cations from between platelets out into the water) and osmosis (the movement of water into the space between platelets) then promote delamination until platelets are completely separated.




For most **VEEGUM**® Magnesium Aluminum Silicate and **VANATURAL**® Bentonite Clay grades, the speed with which platelet separation occurs is directly related to the amount of energy introduced during hydration. Both mechanical and thermal energy accelerate hydration: high shear mixing or the use of warm water will reduce hydration time. The presence of dissolved substances in the water will prolong hydration time by inhibiting the diffusion and osmosis essential to platelet separation.

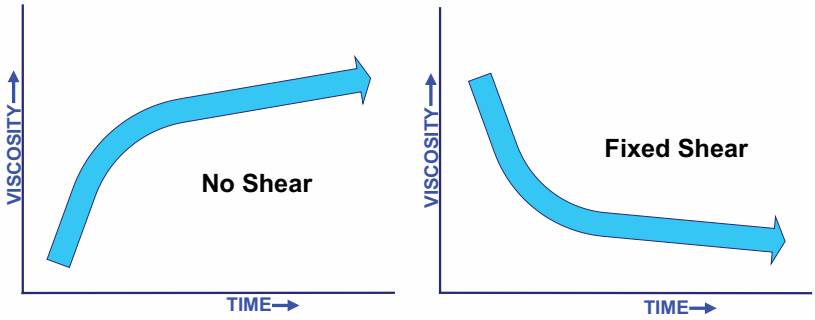
## Clay Rheological Properties

Once the clay is hydrated (i.e., the platelets are separated) the weakly positive platelet edges are attracted to the negatively charged platelet faces. A three dimensional colloidal structure forms, commonly called the "house of cards". The formation of this colloidal structure accounts for the characteristic rheology imparted by these clays. Dispersions of **VEEGUM** and **VANATURAL** clays are pseudoplastic and thixotropic, in addition to contributing useful yield value.

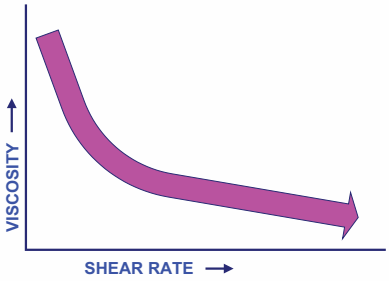


This colloidal structure is particularly valued for its ability to trap and segregate solids, as in a suspension, oils, as in an emulsion, and gases, as in a foam or mousse.

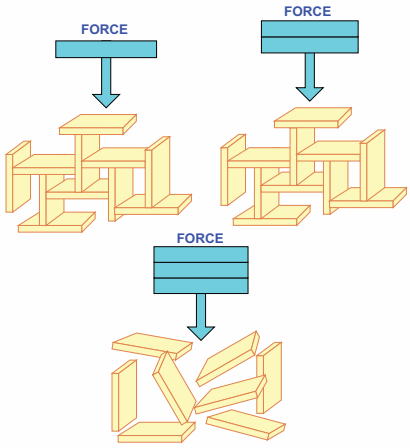
**Rheology** - After the clay is hydrated, the colloidal structure builds rapidly at first, giving a quick increase in viscosity. As time passes, the remaining free platelets take a longer time to find an available site in the structure, so viscosity increases at a progressively slower rate. Conversely, when a given shear is applied, most of the structure is disrupted quickly, with subsequent breakdown becoming more gradual. The dispersions are therefore thixotropic: undisturbed they increase in viscosity over time, and under a constant shear rate they decrease in viscosity over time.




Smectite dispersions are also pseudoplastic, because increasing the rate of applied shear (thereby increasing structure breakdown) results in decreasing viscosities.

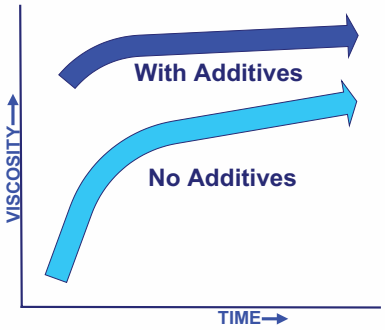



**Yield Value** - The colloidal structure also provides the clay's most useful property - yield value. This is a measure of the resistance of the structure to breakdown. A certain minimum force, the yield value, must be applied to start disrupting the structure. Solids, oils and gases are trapped and segregated by the structure. They must exert a force greater than the yield value to be able to move through the liquid. This means that the greater the yield value, the more stable the suspension, emulsion or foam.

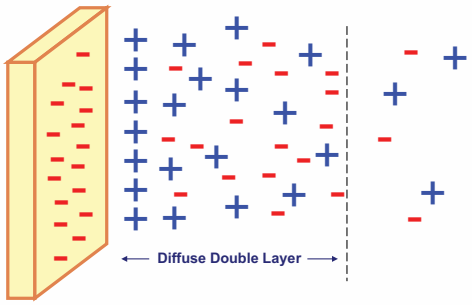



A unique and valuable feature of **VEEGUM**® Magnesium Aluminum Silicate and **VANATURAL**® Bentonite Clay clays is their ability to impart yield value at low viscosity. Stabilization of the dispersed phase is possible even in thin, fluid systems where flowability is important. Most common organic thickeners possess little or no yield value and can only stabilize suspensions, emulsions or foams at high viscosity.

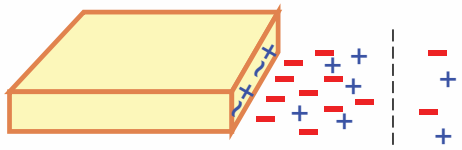
**Rheology Modifiers** - Formulators are more concerned with the behavior of **VEEGUM** and **VANATURAL** clays in the presence of other ingredients, rather than that in water alone. Most water-soluble components will modify the rheological properties of smectite clay, usually beneficially. Salts, surfactants and water-miscible solvents will increase the clay's viscosity and yield value contribution and decrease thixotropy, but still enable a shear-thinning composition.



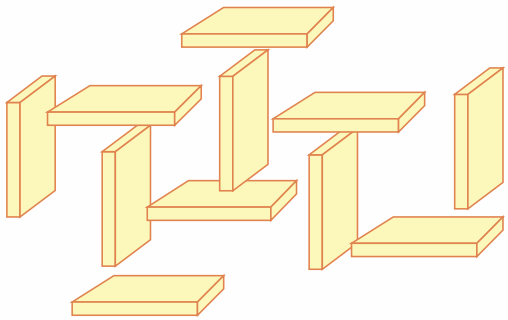

Excess water solubles will destabilize the clay's colloidal structure. This may appear as a relatively stable thick gel or as flocculated masses with syneresis. The effect of electrolytes and water miscible solvents can be explained in relation to double layer theory. According to this model, most of the exchangeable ions in the clay dispersion tend to accumulate, due to electrostatic attraction, near the negative faces of the platelets, but simultaneously have a tendency to diffuse away from platelet surfaces toward the bulk of the water where their concentration is low. The equilibration of these opposing effects causes the formation of a diffuse atmosphere of counterions, with concentration diminishing with distance from the platelet face. A negative "double layer" is thus established, consisting of the negative surface charge plus the diffuse counterions.



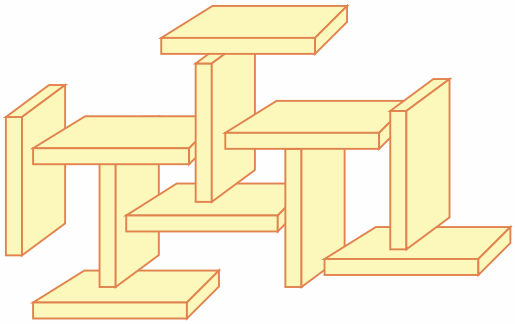

The analogous positive double layer is established in association with platelet edges.



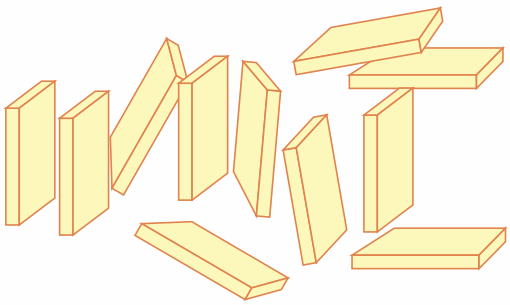
The house of cards colloidal structure is therefore actually based on the interaction of smectite platelet edge and face double layers.



When electrolyte or polar solvent is added to the dispersion, the double layers are compressed. This allows the platelet edges and faces to more closely approach, resulting in a more rigid structure and consequently higher viscosity and yield value.



If the double layers become sufficiently compressed, face-face van der Waals attraction will predominate and the house of cards colloidal structure will be lost, as will thickening and suspending efficiency.



The effect of electrolytes on the clay dispersion depends on cation valence and size as well as concentration. Cations with greater positive charge and/or smaller hydrated radius are more strongly attracted than cations with lower positive charge and/or larger hydrated radius because they can get closer to the clay surface and/or satisfy more negative charges. The higher the cation valence, the less electrolyte the clay can accommodate before the colloidal structure collapses. In short, monovalent cations have the weakest flocculating effect and are the most compatible with **VEEGUM**® Magnesium Aluminum Silicate and **VANATURAL**® Bentonite Clay clays. Divalent cations have a stronger flocculating effect, and trivalent cations the strongest. The following lyotropic series indicates the relative ability of cations to replace one another if present in equivalent quantities based on ionic charge and size (hydrated radius).

$$Al^{3+} > Ca^{2+} > Mg^{2+} > K+ = NH^{4+} > Na^{+} > Li^{+}$$

By the Law of Mass Action, nevertheless, adding large amounts of one cation will replace others, regardless of their position in the lyotropic series.

The properties of individual smectite clays – e.g., viscosity, hydration rate, electrolyte tolerance – vary according to their particular structure, exchange cations and exchange capacity. Each of these properties can be manipulated by the choice of smectite clay, based on location and type, and by blending clays from different locations so as to obtain the desired balance of properties. For example, the blend of smectite clays that make up **VEEGUM K** enable this product to provide greater electrolyte tolerance than **VEEGUM R** while the blend of clays in **VEEGUM R** provide greater viscosity and yield value than **VEEGUM K**. In addition, certain gums, such as xanthan gum and CMC, act as synergists and protective colloids when used together with **VEEGUM** and **VANATURAL** clays. They can significantly improve the compatibility of the clay with relatively high levels of water solubles.

# Vanderbilt Minerals, LLC

A Wholly Owned Subsidiary of R.T. Vanderbilt Holding Company, Inc.


## Vanderbilt Minerals, LLC

33 Winfield Street, P.O. Box 5150, Norwalk, CT 06856-5150
(800) 562-2476 Fax: (203) 855-1220
E-Mail: mineralsales@vanderbiltminerals.com
Web Site: vanderbiltminerals.com


Vanderbilt Minerals, LLC
UL REGISTERED FIRM
ISO 9001:2008 10012164

RESPONSIBLE CARE®
OUR COMMITMENT TO SUSTAINABILITY