The Clay Minerals Society Glossary for Clay Science Project

The Clay Minerals Society (CMS) Nomenclature Committee was asked by CMS Council to produce a glossary of clay science in 2003.

Constraints and goals of the Glossary. The Committee developed several constraints on the development of the glossary: (1) it was decided to produce a glossary of *clay* terms, based on clay science. Terms may have other meanings in other disciplines, but the Committee did not want to include how other disciplines may use the terms (unless it is integral to the definition, e.g., as was the case of "particle size" for "clay"). The definitions provided below are terms *as used in clay science* and thus, this glossary is not a compendium, as is the case for the *AGI Glossary*. However, the definitions do not and should not stray from the basic science definitions as one would have in chemistry and physics. The point here was to include examples and perhaps direct the discussion toward clay science; the definition itself would conform to definitions in the other sciences. Unlike the *AGI Glossary*, where current usage is given even if that usage deviates from the original definition, the CMS *Glossary* provides the original definition and explains how the word may be currently and, perhaps incorrectly, used.

(2) Provisional or tentative definitions were avoided. The glossary may be used in ways that we may be unaware, such as by the legal profession, and the Committee only listed terms that are well defined. Definitions in contention that could not be reconciled in committee were not included. Multiple definitions are provided, if warranted, and discussion is provided on how the terms may have changed in meaning over (recent) time. (3) Established definitions by the International Mineralogical Association (IMA), CMS, and Association Internationale pour l'Etude des Argiles (AIPEA) Nomenclature Committees, or any other international body were not open for discussion. The Committee decided that further explanation may be warranted to show the utility of a term in clay science, but the definition is given unchanged from that provided by the international body. (4) In general, computer-program names and similar names are not part of the *Glossary*, both because such names tend to be ephemeral and because the Society does not advocate the use of a specific program.

The initial effort was not to include mineral and related (i.e., discredited, synonyms, etc.) names, although group names were included in what is now considered Part 1. There are other web sites that have compiled mineral name lists, although descriptions on other websites tend not to be oriented toward clays. The 2018 edition of the Glossary included a first draft of "Part 2. Clay-related materials (excluding exchanged phases)" that covers clay-related minerals, discredited names, and synonyms, with approximately 650 terms. Any natural material that would be commonly found in a clay-related publication are considered in Part 2.

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The Clay Minerals Society Glossary of Clay Science, 2020 version

1:1 layer see *layer*

1*A* see *Ramsdell-style notation*

1*T* see *Ramsdell-style notation*

1*Tc* see *Ramsdell-style notation*

1*M* see *Ramsdell-style notation*

2:1 layer see *layer*

2:1:1 layer previously used to describe chlorite where a 2:1 layer plus an interlayer describes the sheet and layer configuration. This nomenclature is no longer in use, see Guggenheim *et al.* (2006) and references therein. Use 2:1 layer. *Cf.*, tetrahedral sheet, octahedral sheet, layer, interlayer material

2:2 layer previously used to describe chlorite where a 2:1 layer plus an interlayer was summed to two tetraheral sheets and two octahedral sheets. This nomenclature is no longer in use, see Guggenheim *et al.* (2006) and references therein. Use 2:1 layer. *Cf.*, tetrahedral sheet, octahedral sheet, layer, interlayer material

2H_1 see *Ramsdell-style notation*

2H_2 see *Ramsdell-style notation*

2M_1 see *Ramsdell-style notation*

2M_2 see *Ramsdell-style notation*

2*O* see *Ramsdell-style notation*

2*Or* see *Ramsdell-style notation*

2*T* see *Ramsdell-style notation*

3*R* see *Ramsdell-style notation*

3*T* see *Ramsdell-style notation*

6*H* see *Ramsdell-style notation*

6R see *Ramsdell-style notation*

I*a* or **I*b*** see *Ramsdell-style notation for chlorite*

II*a* or **II*b*** see *Ramsdell-style notation for chlorite*

absolute humidity see humidity

absorption edge (X-ray) The -"edge" concept (as in an "absorption edge") is often used wherever there is a sharp drop (or increase) in a characteristic of a graph. For example, graphs of X-ray absorption vs energy (or wavelength) show a sharp decrease in absorption for foils of specific metals at distinct X-ray wavelengths, and these wavelengths mark the metal's absorption edges. Metal foils have been used to reduce or remove extraneous X-ray wavelengths in (early) X-ray experiments; more modern experiments use a monochromator crystal. Because these absorption edges are characteristic for the metal, they may be used to identify the local atomic structure of the metal in a phase in spectroscopic studies, such as XANES (X-ray Absorption Near-Edge Structure) or EXAFS (Extended X-ray Absorption Fine Structure).

absorption In clay science, absorption occurs where the sorbate enters internal layers, voids, or pore spaces within the sorbent (usually, clay material). Other scientific fields, often do not specify a mechanism.

accessory mineral a mineral present in a rock which is not essential for the classification of that rock. Characterizing accessory minerals are often used as modifiers to the rock name, for example, as in nepheline basalt.

acicular a crystal habit composed of radiating masses of slender needle-like crystalline phases

acid clay see acid activated clay

acid-activated clay a clay (most often a Ca-bentonite) treated with concentrated acid in aqueous suspensions and, depending on how the clay is to be used, at various elevated temperatures and subsequently washed, dried, and pulverized. The modification results in enhancements in surface acidity, increased specific surface area, and higher porosity, all of which improve edible-oil bleaching or adsorption properties. Surface acidity for a clay was noted by K. Kobayashi in 1899 in Japan, and he termed the clay as "acid clay". Hence, "acid clay" and "activated clay" are separately described in Japan. More recent adaptations of acid activation applied to other fuller's earth clays (e.g., clays rich in sepiolite or palygorskite or mixture of palygorskite and montmorillonite) have either improved upon or eliminated processing steps associated with "classical" acid activation to produce different bleaching clay products for refining numerous edible oils. It is common to include the activation process when describing activated clays, e.g., "thermal-activated clay", "Na_2CO_3-activated clay". See also bleaching clay, fuller's earth; *Cf.*, activated clay, beneficiation, bleaching clay

activated clay a clay treated either chemically, thermally, or physically (milling) to improve its properties or increase its reactivity, e.g. by increasing the specific surface area and porosity, creating broken bonds and lattice distortions. *Cf.*, acid activated clay, alkaline activated clay, thermally activated clay, ageing

activation energy The minimum energy two molecules, atoms, or ions must have to initiate (by colliding) a reaction is called the activation energy, E_a, and has units of kilojoules per mole.

active principle a pharmaceutical term denoting the active ingredient(s) in a drug. For a drug containing clay, the active principle may be loaded in clay lumen (e.g., halloysite, zeolite) or adsorbed to clay surfaces, including interlayer surfaces (e.g., as found in smectite). The clay portion, as an inactive carrier or coating, is referred to as the excipient or vehicle. The excipient is often used to improve the physical appearance, taste, smell, or smoothness of a pill or to promote disintegration (time release) of capsules or pills. *Syn.*, active ingredient, bulk active, *Cf.*, aesthetic medicine, antibacterial clay, excipient, geotherapy, healing clay, lumen, medicinal clay, pelotherapy

activity In thermodynamics, activity refers to an 'effective' concentration, which takes nonideal behavior into account. Thus, ion-to-ion interactions, such as charge shielding, may affect the activity by attractive or repulsive intermolecular forces. The activity of a dissolved species is calculated as $a_i = \gamma_i m_i$ where γ_i is the activity coefficient and m_i is the molality. Activity is the term used to describe concentrations in solutions, whereas fugacity describes the activity of a gas.

activity, clay Skempton (1953) defines clay activity, or the colloidal activity of clay, as the ratio of the plasticity index to the percentage of the clay-size fraction. According to Skempton, three types of activity can be determined: inactive (activity <0.75), normal (activity 0.75 to 1.25) and active (activity > 1.25). See low-activity clay, high-activity clay

activity number In geotechnical engineering, the activity number (A) of a soil is the ratio of the plasticity index to the mass percentage of the clay fraction. See also Atterberg limits, consistency number, liquid limit, plastic limit, plasticity index, shrinkage limit.

adatom an atom attached to a substrate. *Syn.*, adsorbed atom

adhesion Adhesion refers to the attractive forces between two or more chemically dissimilar molecules or surfaces of different materials (e.g., glass vs. water, clay vs. sand). Thus, wet-clay and dry-clay particles tend to adhere to different surfaces. *Cf.*, cohesion

admicelle a micelle structure adsorbed to a surface. See micelle.

adobe durable, sun-dried, hardened bricks made from mixtures of water, clay, silt, sand and straw, or other fibrous organic materials

adsorbate any substance which, in molecular, atomic, or ionic form, will penetrate into and be retained by another (liquid, solid, gel, etc.) material. *Cf.*, Solid-state diffusion, adsorbent

adsorbed water H_2O molecules attracted to and adhered to by atomic forces at internal or external surfaces of a phyllosilicate or other material in thicknesses of one or more molecules. The term "water" (rather than "H_2O") is not precisely used here because "water" is a (liquid) phase.

adsorption, anion the adsorption of anions on basal OH surfaces of a phase where structural hydroxyl groups are replaced by other anions, or on particle edges where unsatisfied positive bonds occur; exchange of edge hydroxyls also may occur (modified from O'Bannon, 1984).

adsorption, cation the adsorption of cations on basal surfaces where negative charges occur, possibly as a result of isomorphous replacement within the structure, and/or adsorption on mineral surfaces where unsatisfied charges may occur often where there are incomplete coordination units. Surface adsorption is common on the basal oxygen atom plane of the 2:1 layer of phyllosilicates. Edge adsorption predominates in kaolin-type phyllosilicates having 1:1 layers (modified from O'Bannon, 1984).

adsorption edge, surface characterization For graphs in which the concentration of adsorbate per unit adsorbent is on the y axis and pH is on the x axis (adsorption vs pH plot), an adsorption edge (sharp increase in adsorption at a specific pH) for an oxide or phyllosilicate surface occurs when the plotted curve shows an "S-shape". An adsorption edge is commonly encountered for many cations adsorbed from a fluid onto the surface of a mineral or other solid substance (e.g., biological matter, glass). *Cf.*, adsorption envelope

adsorption envelope For graphs in which the concentration of adsorbate per unit adsorbent is on the y axis and pH is on the x axis (adsorption vs pH plot), an adsorption envelope occurs if adsorbed concentration decreases with pH, which is commonly encountered for many anions adsorbed from a fluid on an oxide or phyllosilicate surface. *Cf.*, adsorption edge

adsorption isotherm a plot of the amount of a substance adsorbed per unit surface area (or in less rigorous terminology as per unit mass) of a solid or liquid as a function of the equilibrium concentration of the adsorbate, at a specific temperature and pressure.

adsorption the process of attraction and adherence of atoms, ions, or molecules from a (gas, liquid, etc.) solution to a surface.

aerosol see suspension

aesthetic medicine Aesthetic medicine is a discipline involving all medical methods, including the application of materials such as some clays, to skin for cosmetic purposes (e.g., to tighten skin, add/change color, stimulate circulation, or reduce a scar). Such procedures are generally non-invasive or minimally invasive. Procedures that are non-invasive or minimally invasive are typical. *Cf.*, active principle, antibacterial clay, geotherapy, healing clay, medicinal clay, pelotherapy

ageing Ageing refers to a) a process where the physical properties, for example the rheology, of wet clay are improved by allowing the clay to sit undisturbed for a period, sometimes for years but more often for days or months, to allow the water to become more homogeneously distributed or to promote the growth of microorganisms. An improvement in plasticity by ageing is important for pressing and drawing of the clay for commercial production of ceramics. *syn*., aging, maturation; b) in soil mechanics, aging is also referred to the process of secondary consolidation or drained creep. *cf*., drained creep, secondary compression

agglomeration see flocculation

aggregation see flocculation

aging see ageing

air classification a process of separating, fractionating, or manipulating fine particulate materials (or lighter particles) by gravitation in a vertically directed, usually upwards, moving air stream. This method is typically used for particles with sizes greater than 1μm. The smaller or lighter particles rise to the top (overflow) above the coarser heavier fractions (underflow) because their terminal velocities are lower than the initial velocity of the rising fluid. The terminal velocities of various particle sizes in any media is calculated by Stokes' law. See also Stokes' law; *Syn*., elutriation

airfloat kaolin a process where kaolin is dried, transported on a column of rapidly moving air through a pulverization mill, and passed through a cyclonic air-classifier where coarse, sand-size particles are removed as gangue or returned to the mill for further size reduction. The term is used in the kaolin industry and refers to the less costly, dry-processed and air-classified powder products where bulk chemistry is of concern, but where purity, handling, and appearance may be less important. *Cf*., air classification

alite see calcium silicate (CS) phases

alkali activated clay An alkali activated clay involves the addition of alkali or alkaline earth metal hydroxide solutions such as NaOH, KOH or $Ca(OH)_2$ to partly or completely dissolve clay mineral particles. Clay minerals are commonly calcined prior to alkali activation to increase the amount of dissolved species. After hardening, the product is a geopolymer, and the process is referred to as alkaline activation, although both alkali and alkaline earth elements may be involved. *Cf*., activated clay, alkaline activated clay, geopolymer, thermally activated clay

alkaline activated clay An alkaline activated clay is a clay treated with Na_2CO_3 (soda activation) to increase the proportion of Na-exchanged smectite or the addition of alkaline solutions to increase the pH of the clay aqueous suspension. In either case, bacterial growth is promoted (ageing). *Cf*., activated clay, ageing

alkylammonium layer charge method a method to determine the layer charge of phyllosilicates with 2:1 layers, primarily those phyllosilicates with interlayer-cation exchange capability, interstratified complexes, and micas. The layer charge is determined based on changes in basal spacing [*d*(001) value] as derived from various alkyl-chain lengths (C6-C18) of alkylammonium cations, following exchange in solutions with a series of *n*-alkylammonium hydrochloride salts (Lagaly and Weiss, 1969; Lagaly and Weiss, 1975). Alkylammonium-exchanged, low-charge smectites produce smaller basal-spacing values than higher-charge smectites or vermiculites. Greater expansion is produced by *n*-alkylammonium salts with longer alkyl chain lengths. Layer charge is estimated from the monolayer to bilayer transition alkyl-chain length. See Lagaly (1994) for further description, problems, and history. *Cf.*, alkylammonium organoclay bilayer, alkylammonium organoclay monolayer, alkylammonium organoclay paraffin complex, alkylammonium organoclay pseudotrilayer, organoclay

alkylammonium organoclay bilayer see bilayer, alkylammonium organoclay

alkylammonium organoclay monolayer an interlamellar arrangement of one layer of alkylammonium cations with the C-C-C plane of the alkyl chains ($n < 8$) parallel to the (001) plane of the 2:1 layer to produce a characteristic 13.6-Å spacing of a phyllosilicate. The positively-charged end groups (e.g., NH_3^+) of the alkylammonium cations are attached to alternate siloxane surfaces in the interlayer. See Lagaly and Weiss (1975); Lagaly (1994). *Cf.*, alkylammonium layer charge method, organoclay

alkylammonium organoclay paraffin complex an interlamellar arrangement of alkylammonium cations with the positively-charged (polar) end groups (e.g., NH_3^+) of the alkylammonium cations attached to the interlayer silicate surfaces of a 2:1 phyllosilicate. The alkyl chains are tilted from a perpendicular orientation with respect to the (001) surfaces, and this orientation produces basal spacings of >22Å. The angles between the alkyl chain axes and silicate 2:1 layers increase with layer charge and range from 50 to 60° in vermiculites and to 90° in micas. See Lagaly and Weiss (1969; 1975); Lagaly (1994). *Cf.*, alkylammonium layer charge method, alkylammonium organoclay bilayer, alkylammonium organoclay monolayer, alkylammonium organoclay pseudotrilayer, organoclay

alkylammonium organoclay pseudotrilayer An interlamellar arrangement of alkylammonium cations with the positively-charged (polar) end groups (e.g., NH_3^+) of the alkylammonium cations attached to the interlayer silicate surfaces of a 2:1 phyllosilicate. Kinks in the alkyl chains shift the (non-polar) alkyl group tails between other alkylammonium alkyl chains to form a pseudotrilayer with a characteristic spacing of ~22Å as determined from the thickness of three alkyl chains (Lagaly and Weiss, 1975; Lagaly, 1994). *Cf.*, alkylammonium layer charge method, alkylammonium organoclay bilayer, alkylammonium organoclay monolayer, organoclay

alkylammonium salt see quaternary alkylammonium salt

alligator skin texture An “alligator hide/skin” texture relates to a macro-texture observed on exposed and weathered clay surfaces. The texture evolves from polygonal shrinkage cracks that develops from bentonites with low dialatancy. See also popcorn texture.

alligator hide texture see alligator skin texture

alloy see suspension

alteromorph An alteromorph is an alteration product of a crystal that preserves the external anhedral form of the precursor mineral. The alteromorph may have a different chemical composition and/or crystal structure than the precursor crystal. The alteromorph can result from replacement in the solid state or by fluid interactions. *cf.,* centripetal replacement, pseudomorph

alumina Alumina refers to Al_2O_3 chemical composition only and the term does not imply a structure. The term commonly is used to describe a mineraloid or a glass, as in a alumina-rich glass. Thus, alumina does not specifically refer to corundum or other alumina-rich phase (e.g., boehmite, diaspore). *Cf.*, mineraloid

aluminol group a surficial AlOH group (see *silanol group*), which is able to incorporate or dissociate protons. See *silanol group*

aluminosilicate "In general, silicates which contain tetrahedrally coordinated aluminum are called aluminosilicates in contrast to silicates containing octahedrally coordinated aluminum for which the term aluminum silicates is used..." (Liebau, 1985, p. 13). Although this is the classic definition of aluminosilicate, many texts use the term inconsistently. For example, kyanite and andalusite, traditionally considered part of the "aluminosilicate group" with sillimanite, do not have tetrahedrally coordinated Al, although they are closely related (structurally and geologically) to each other and sillimanite. Clearly, taking the first part of definition by Liebau (1985) as the basis of the definition, the second part should not be limited to aluminum in octahedral coordination only. Phyllosillicates are generally considered aluminosilicates, because most phyllosilicates do have Al substitution for Si, but not all do (and those minerals without tetrahedral Al present, but with Al in other polyhedral coordinations are more properly referred to as "aluminum silicates").

aluminum silicate see aluminosilicate

amorphous a term describing a non-crystalline phase where the constituent components (i.e., atoms, ions, molecules) are without long-range order, i.e., not related by translation periodicity. There are many variations of such order or lack of order, for example, glasses commonly occur where atoms are arranged as coordination groups of tetrahedra (e.g., four oxygen ions in coordination about a silicon ion). Such tetrahedra share vertices to define local structure similar to that of crystalline phases; however, such groups of atoms are not related by long-range translation periodicity. This type of short-range order is much different than a simple random positioning of atoms.   Amorphous character can be described by the nature of the analysis, e.g., such that the material may produce an X-ray diffraction pattern without discrete maxima, hence, "X-ray amorphous". *Cf.*, non-crystalline, crystalline

anchizone a zone of transition from late diagenesis to low-grade metamorphism. The anchizone is defined by Kübler indices between 0.42 and 0.25 in mudrock lithologies. *Cf.*, diagenesis, Kübler index

Ångstrom, Å a non-SI unit of measurement equal to 10^{-10} meters, e.g., 1 Å = 0.1 nm.

anhedral see crystal

anion see ion

anionic clay a term referring to a group of clay minerals containing (often brucite-like) layers that have a net positive structural charge and linkage of the layers by way of an anionic (negative) interlayer. The "clay" aspect refers to a (natural) fine-grained material that under appropriate water content will exhibit plasticity and will harden when dried or fired. The term "anionic clay" has the potential for confusion because both anions and cations are structural components. More traditional swelling clays, like smectite or vermiculite, have silicate layers linked by interlayers containing cations, but are generally not referred to as "cationic clays." More precise and descriptive synonyms are in common usage, and these synonyms may be less confusing, and thus, are preferred over the term "anionic clay". *Syn*., double metal hydroxide, hydrotalcite-like, layered double hydroxide, LDH *Cf.*, double metal hydroxides

anisotropy a description of material that has properties (optical, hardness, conductivity, etc.) that differ depending on the direction of measurement. These properties, when related to crystals, are dependent on composition, atomic structure, and structural defects. Nondirectional properties, such as density, also exist. When related to composite materials, such properties may be determined by layering, the properties of the constituent materials, etc. *Cf.*, isotropy

anneal to heat and then cool slowly to reduce internal stress, which commonly involves new grain crystallization toward an equilibrium phase assemblage and texture. Usually relates to glasses and metals.

anode see electrode

antibacterial clays Antibacterial clays are clays that kill bacteria by various means, including *but not limited to* the chemical transfer of toxins, elimination of nutrients, or physical disruption of metabolic functions. *Cf.*, active principle, aesthetic medicine, geotherapy, healing clay, medicinal clay, pelotherapy, zeta potential

antiferroelectric a property of materials where there is an antiparallel alignment of electric moments that cancel out over the entire crystal. The "ferro" aspect of the word is a misnomer because iron is not a usual constituent; the word derives from analogy to antiferromagnetism.

Cf., antiferromagnetism

antiferromagnetism a property of material where magnetic moments have antiparallel spins so that there is complete canceling and hence no magnetic attraction or repulsion effects. Antiferromagnetism coupling effects are removed by heating to the Néel temperature, and the material reverts to paramagnetism.

argillaceous an adjective that describes a rock or sediment that contains clay

argillan see cutan

argillite see lutite

Árkai index The powder X-ray diffraction pattern of fine-grained chlorite was used to obtain information about apparent chlorite "crystallinity" by M. Frey (Frey, 1987) and others, and by Arkai (1991) to correlate the reactions involving smectite-muscovite and smectite-chlorite with the Kübler index (and other metamorphic grade-indicating characteristics). Because diffraction patterns are affected by the presence of a diversity of defects, mean crystallite sizes, and other features, it is unclear if "crystallinity" is actually being measured and thus, the index should not be characterized as a "crystallinity" index. *Cf.*, crystalline, crystallinity index, Hinckley index, Kübler index

Arrhenius Equation a formula describing the temperature dependence of a rate constant (k) for a chemical reaction: $k = Ae^{-E_a/RT}$ where E_a is the activation energy, R is the ideal gas constant and T is the temperature (Kelvin). A is the pre-exponential factor.

asbestiform minerals with the same shape characteristics as asbestos. *Cf.*, aspect ratio, asbestos, asbestosis

asbestos a general commercial term for two fibrous silicate-mineral groups: chrysotile, the fibrous serpentine mineral, and fibrous amphiboles (amosite, crocidolite, anthophyllite, tremolite, and actinolite) and these two groups are considered hazardous by U.S. regulatory agencies (e.g., Occupational Safety and Health Administration, OSHA). Asbestos minerals are incombustible, make excellent thermal and electrical insulators, resist chemical attack, and have high tensile strength. In addition to being fibrous, other characteristics include flexibility and the ability of fibers to be separated (often capable of being woven). The aspect ratio (i.e., length-to-width ratio) is often defined (as stated within Federal Register, June 8, 1992) as at least 20:1 (and often greater than 100:1) by mining or stone companies. Actinolite and tremolite have no commercial value. Amosite ("brown asbestos") is a variety of grunerite (along the cummingtonite-grunerite join) whereas crocidolite ("blue asbestos") is a variety of riebeckite. Asbestos minerals have been implicated as pathogenic when inhaled, although the minerals are not equally pathogenic with chrysotile, which is considerably less dangerous than the amphiboles. OSHA (Federal Register, June 8, 1992) considers asbestos fiber dimensions as the best indicator of significant "fiber pathology". OSHA considers fiber-dimension lengths most pathologically active at greater than

5 micrometers and these fibers generally have aspect ratios of greater than 10:1 with most greater than 20:1. *Cf.*, aspect ratio, asbestiform, asbestosis

asbestosis Asbestosis is a disease that results in fibrosis of the lung from the inhalation of asbestiform particles, such as fibrous serpentine (chrysotile) and fibrous amphibole (crocidolite, amosite, anthophyllite, tremolite, actinolite), which can lead to mesothelioma (cancer). The amphiboles have a much greater residence time in the lung than the serpentines, which dissolve more readily at the pH of lung tissue (Hume and Rimstidt, 1992; Werner et al., 1995). See asbestos, asbestiform, *cf.*, asbestiform, asbestos, aspect ratio,

aspect ratio The aspect ratio is the ratio of the smallest dimension to the longest dimension. For fibers, the aspect ratio is the ratio between the width to the length. NIOSH defines asbestos, for example, with a length:width ratio (also commonly referred to as "aspect ratio") of predominantly >3:1 fibers. For platy materials, such as clay minerals or polymer/clay nanocomposites, the properties of the composite are strongly impacted by the morphology of the particle. For montmorillonite the aspect ratio (height to diameter of plate) is generally 1:150. In industry, this ratio is commonly expressed simply as an aspect ratio of 150. The aspect ratio of platy and acicular morphologies is one measure of the anisotropy of nanoparticles.

asymmetric unit the smallest part of a unit cell from which the entire unit cell can be generated by applying all symmetry operators present

at-rest condition In geotechnical or soils engineering, the at-rest condition refers to a stress state where a soil or clay deposit is subject to three-dimensional (mutually perpendicular) stresses such that the soil/clay body only deforms vertically (i.e., along the z axis) but not laterally (i.e., along x and y axes). The ideal at-rest condition exists in a soil unit beneath a level, infinite-sized ground surface. In engineering practice, sites with level ground surface and the horizontal dimensions much greater than the vertical dimension (e.g., lake bed sediments with a horizontal surface), can be treated as an at-rest condition. For a component of soil or clay at the at-rest condition, the strains in the x and y directions are zero, and hence the vertical strain is the same as the volumetric strain (= change in volume divided by the original volume). Understanding the at-rest condition is essential for the design of structures situated on or in soil or clay. *Syn.*, K0 condition.

Atterberg Limits a designated series of parameters (i.e., water-content properties) in geotechnical engineering used for identifying, describing, and classifying fine-grained soils and clays or loams used for (ceramic) coarse ware. These parameters, which originally included six "limits of consistency" (the upper limit of viscous flow, the liquid limit, the sticky limit, the cohesion limit, the plastic limit and the shrinkage limit) are now typically limited to the "liquid limit", the "plastic limit" and, sometimes, the "shrinkage limit". Atterberg limits are determined on the basis of mass of water per mass of the dry soil solid by specific test methods, as standardized by ASTM Standard D4318 – 05 or other standard tests, and expressed in percent. See Mitchell (1993). See also activity, consistency number, liquid limit, plastic limit, plasticity index, shrinkage limit

authigenic refers to rock constituents or minerals that have formed in place and were not transported. Such materials have formed either at the same time as the rock in which they are found or after the formation of the rock. The term is also applied to minerals that are clearly the result of new crystal growth on older crystals of the same kind, *e.g.*, K-rich feldspar overgrowths may be referred to as authigenic overgrowths.

autocorrelation function, molecular dynamics In a molecular dynamics simulation, the autocorrelation function is a time-dependent function calculated from the product of a quantity at a given time relative to an initial reference time. Specific autocorrelation functions are used to calculate vibrational spectra. For example, the velocity autocorrelation function is used to determine a power spectrum, and the dipole moment autocorrelation function is used to calculate the infrared spectrum.

b-fabric The fabric of a soil or sediment ground mass where the fine material is described from the birefringence ("b-fabric") based on the interference colors in thin section under crossed polarizers (after Bullock et al., 1985). Syn. clay birefringent fabric; see listing. Types of b-fabric relating to clay or other fine material include:

cross striated b-fabric Similar in description to reticulate striated b-fabric but with birefringent streaks showing non-perpendicular angular relationships in the ground mass.

granostriated b-fabric A b-fabric consisting of clay particles oriented parallel to skeletal grain surfaces.

monostriated b-fabric A fabric with birefringent streaks that are not associated with natural surfaces and occur isolated in the ground mass.

mosaic-speckled b-fabric A speckled b-fabric where a mosaic-like pattern occurs of coalescing birefringent regions or speckles.

parallel striated b-fabric A fabric with birefringent streaks that are not associated with natural surfaces and occur in parallel or sub- parallel sets in the ground mass.

porostriated b-fabric A striated b-fabric that consists of clay particles oriented parallel to the surface of pores.

reticulate striated b-fabric A ground mass with two sets of birefringent streaks intersecting at right angles. The streaks are not apparently associated with natural surfaces.

speckled b-fabric A ground mass (or pedoplasma or s-matrix) of predominantly clay where zones of birefringence show small (several microns), equidimensional, or slightly prolate regions or "speckles".

stipple-speckled b-fabric A speckled b-fabric that consists of isolated regions or speckles.

strial b-fabric A ground mass composed mostly of clay characterized by preferred parallel birefringence orientation as an entity. This general orientation is commonly inherited from sedimentary processes and can occur in one or two preferred directions, "unistrial" and "bistrial", respectively.

striated b-fabric A ground mass of predominantly clay with elongated birefringent zones or streaks showing nearly simultaneous extinction, commonly several hundred microns in size.

ball clay a fine-particle size, plastic, sedimentary kaolinitic clay layer with minor to abundant organic matter, important in the manufacture of ceramics. Typically found in association with lignite layers. *Cf.*, underclay, seat rock

balneotherapy the treatment of diseases, injuries, and other physical ailments by medicinal procedures in mineral springs, medical peloids or mud baths, inside the facilities of Health Resort Medicine Centers (Gutenbrunner et al., 2010). Balneotherapy is broadly interpreted to include hot or cold spring water baths, drinking of medical mineral waters rich in gases, salts, silica, sulfur, etc. Crenobalneotherapy is the term used in both France and southern Europe countries. *Balnea* is Latin for 'hot baths'.

basal surface the terminating surface (or basal plane) parallel to the atom planes in the repeating layers in clays and layered minerals. Common usage has broadened the meaning to include (internal) surfaces that parallel the terminating surface. If the repeating layers have a stacking direction along [001], the *c* crystallographic axis, then the atom planes in the repeating layers are the (00*l*) planes (parallel to the plane containing the two lateral axes, *a* and *b*). *Syn.*, basal plane

basal plane see basal surface

basal reflection a diffraction X-ray peak from a layer material originating from those atomic planes which comprise the layers (i.e., parallel to cleavage). For most layer silicates, basal reflections are of the Miller index type: 00*l*, where *l* is an integer. The *d* values of the basal reflections may be used to obtain *c* Sin(beta), which is the repeat distance perpendicular to the plane of the layers. The *c* Sin(beta) value is usually an indicator of the structure unit and thus, the type of phyllosilicate, assuming that no semi-random interstratifications occur in the phase (which can cause a displacement of the basal reflection positions). For example, mica minerals have a value of about 10 A and chlorite minerals have a value of about 14 A.

batch reactor a reaction vessel without inflow or outflow. Batch reactors are commonly used for sorption experiments and, less commonly, for mineral growth and dissolution experiments. *Cf.*, continuously stirred tank reactor, chemostat, plug flow reactor

bauxite the rock term for an aluminum ore consisting of primarily hydrous aluminum oxides [gibbsite, $Al(OH)_3$; boehmite, AlO(OH); and diaspore AlO(OH)], often mixed with iron oxyhydroxides (goethite, FeO(OH), and hematite, Fe_2O_3), kaolinite, and small amounts of anatase (TiO_2). Most bauxite deposits result from weathering of a variety of Al-rich source rocks that are low in comparatively stable silicates. Bauxite deposits are related to paleo-tropical or subtropical climate rather than lithology, especially where long periods of tectonic stability permitted "deep and thorough" weathering of the precursor rock. *Cf.*, bauxitic clay

bauxitic clay clay material containing minerals rich in their bulk aluminum content (e.g., gibbsite, boehmite, diaspore). This material is used for making refractories or as an ore for aluminum metal. Also see bauxite

BCF theory (Burton, Cabrera, Frank) BCF theory describes crystal growth as nucleation and further crystallization by way of layer-by-layer attachment at edge, step, or kink sites on the surface of the growing crystal, as a function of the saturation state of the parent solution. Nucleation can occur at surfaces, dislocations, or impurities. The kinetics are influenced by temperature, impurity concentration, etc.

beidellite-type montmorillonite As described by Schultz (1969) based on chemical and thermal analysis, beidellite-type montmorillonite is a type of montmorillonite characterized by a large net negative layer charge of -0.85 to -1.20 per $O_{20}(OH)_4$, with tetrahedral substitutions causing more than 50% of the total layer charge. Current (chemical) nomenclature for montmorillonite is that it is an Al-rich, dioctahedral smectite with an ideal structural formula of $(Al_{3.15}Mg_{0.85})Si_8O_{20}(OH)_4X_{0.85}.nH_2O$ with layer charge from primarily octahedral substitutions of Mg, whereas beidellite has a net layer charge that occurs from tetrahedral substitutions of Al, with an ideal structural formula of $Al_{4.0}(Si_{7.15}Al_{0.85})O_{20}(OH)_4X_{0.85}.nH_2O$. The term"beidellite-type montmroillonite" is obsolete and should not be used.

belite see calcium silicate (CS) phases

beneficiation a) a process or processes to concentrate an ore mineral. The British equivalent is "mineral dressing". b) the process of improving the performance characteristics of an industrial clay by processing and/or the addition of chemical additives, e.g., bentonite.

bentonite, **white** a generic industrial classification for a white- or nearly white-colored bentonite clay (primarily smectite, illite, and/or interstratifications), generally low in iron-bearing and organic phases, and often containing some kaolin and/or minor silicate accessory minerals (quartz, feldspar, opal, etc.). White bentonite is a common base material for many value-added industrial and consumer applications and products.

bentonite a) Mineralogical/Petrological term: A soft, plastic, light-colored rock composed primarily of clay minerals of the smectite group, particularly the clay mineral montmorillonite, which typically forms from chemical alteration of glassy volcanic ash or tuff under marine or hydrothermal conditions. Bentonite may contain accessory crystal grains that were originally phenocrysts in the parent rock as well as secondary authigenic mineral phases such as K- rich feldspar. Diagenetic or low-grade metamorphic alteration can modify the smectite to a variety of interstratified illite-smectite minerals, resulting in materials known as K-bentonites. b) Industrial term: A highly colloidal and plastic clay material, primarily composed of the clay mineral montmorillonite, that is commonly used in drilling mud, as a foundry sand binder, in cat litter, animal feed, cements, ceramics and various other industrial activities and products. Sodium bentonite swells significantly when exposed to water (to ~12X) whereas calcium bentonite has minimal swelling capability (to ~3X). *Cf.*, tonstein

BET see Brunauer-Emmett-Teller (BET) for specific surface area analysis

bilateral see mirror plane

bilayer, alkylammonium organoclay an interlamellar arrangement of two monolayers of alkylammonium cations [each monolayer has a C-C-C plane of the alkyl chain parallel to the (001) plane of the silicate 2:1 layers] between 2:1 layers of a phyllosilicate. The positively-charged end groups (e.g., $–NH_4^+$) of the alkylammonium cations are attached to the interlayer silicate surfaces to produce a characteristic *d* value depending on the identity of the alkylammonium cation. *Cf.*, alkylammonium layer charge method, alkylammonium organoclay, bilayer, monolayer, organoclay

bilayer, phyllosilicate Between the 1:1 or 2:1 layers of a phyllosilicate, a bilayer is an arrangement within the interlayer of two planes of molecules. The planes are only approximate, but the spacing seem to suggest planar features. For a bilayer hydration shell, the H_2O molecules are in an octahedral coordination around a central cation, with three H_2O above and three below the cation, and the spacing appears as two H_2O planes or “layers”. The spacing is generally not affected by the cation because the cation is small and resides well within the hydration shell of H_2O. Thus, the bilayer only refers to the two planes of H_2O molecules. *Cf.*, alkylammonium organoclay bilayer

bilayer a double layer of atoms or molecules. In clay science, an example would be an alkylammonium organoclay. See bilayer, phyllosilicate for an example. *Cf.*, alkylammonium organoclay bilayer; bilayer, phyllosilicate; monolayer, phyllosilicate

binder a solid material that holds (binds) other materials or phases together. Binders are often formed from liquid or pasty suspensions which harden upon drying, both in artificial (e.g. cement in a masonry) and natural systems (e.g. carbonate cement in sandstones). Hardening may be solely by evaporation or by precipitation of new phases (e.g., calcite). *Cf.*, cement, concrete, Portland cement

binding site, clay mineral a site on a clay mineral surface available for electrostatic attraction between oppositely charged species, including metal coordination bonding, and anion or polar-molecule attractions, etc. Binding sites commonly occur: (1) where bonds are broken at particle edges (terminal edges) leaving a net positive charge and a possible under-bonded arrangement where bond lengths adjust accordingly to approach overall charge balance. Alternatively, any anion may compensate for the broken bond, with $(OH)^-$ most common (and thus these sites may be affected by pH). (2) to charge balance isomorphous substitutions that occur within the 2:1 or 1:1 layer, for example, cations in the interlayer of smectite compensate for the (permanent) negative layer charge on the basal plane atoms. *Cf.*, edge site

binuclear complex A binuclear complex refers an entity of atoms (i.e., a complex or more appropriately, a molecular entity or coordination entity) with two central ions (by extension, a mononuclear complex has one central ion, a trinuclear complex has three, and polynuclear complexes have more than three). The central ion is a metal ion and an electron acceptor, with ligands as electron donors. If surface sites are involved, binuclear refers to a ligand (L) binding to two metal (M) surface sites; if a ligand is bound to only one site, the adsorption complex is termed mononuclear. See figure below.

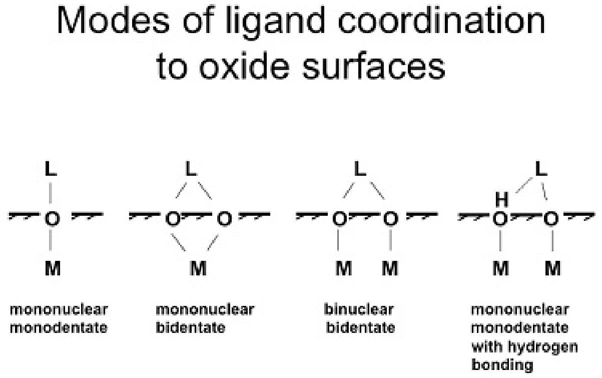

Figure 1. Illustration of mononuclear and binuclear (inner-sphere) complexes of adsorbed metal ions on a surface. See binuclear complex. From Maurice (2009), with permission.

bioaccumulation a process whereby an element or compound is incorporated into or concentrated on the surface of an organism, possibly transformed into another compound, and retained. The concentration of the element(s) or compound(s) in the biota may be greater than its concentration in the media from which it was derived. The process is of particular concern for toxins, pesticides, etc.

biofilm a microbial community generally supported by a surface and held together by extracellular attachment features such as exopolysaccharides (EPS) in a distinct 3-dimensional shape or architecture. Biofilm matrix may also include abiotic components, such as clay or other mineral particles, corrosion products, etc. that may act as support and/or as sources of nutrients.

biological weathering a biological process that produces either a chemical or physical breakdown of minerals or rocks. See weathering, physical weathering, chemical weathering

biologically controlled mineralization a biomineralization process where the cellular activities of an organism directly control mineral nucleation and growth, the location of nucleation, and mineral morphology. The process may be extracellular, intercellular, or intracellular. Traditional definitions of minerals preclude a biological-process origin of minerals, but such definitions are being challenged, see the definition of "mineral" for a more classic approach. *Cf.*, mineral, biologically induced mineralization, biomineralization

biologically induced mineralization a biomineralizaton process where solution conditions and/or surfaces for heterogeneous nucleation are altered by the cell to promote mineralization. However, the cell does not directly control the type of mineral formed or habit. Traditional definitions of minerals preclude a biological-process origin of minerals, but such definitions are being challenged, see the definition of "mineral" for a more classic approach.
Cf., biomineralization, biologically controlled mineralization, mineral,

biomineralization the process whereby living organisms catalyze or otherwise mediate mineral formation. Traditional definitions of minerals preclude a biological-process origin of minerals, but such definitions are being challenged, see the definition of "mineral" for a more classic approach. *Cf.*, biologically controlled mineralization, biologically induced mineralization, biomineralization, mineral

birefringence an optical property whereby a crystal has more than one index of refraction. An optically clear calcite rhombohedron shows a doubling of images as a result of birefringence, i.e., double refraction.

biscuit see bisque

bisque a) unglazed ceramic that has undergone firing; b) the dried, but not yet fired, enamel coating. The bisque firing temperature is that initially used to stabilize the ceramic prior to glazing. Syn., biscuit

bleaching earth see bleaching clay

bleaching clay used in decolorizing oil products, typically fuller's earth or bentonite, by adsorption. For example, bleaching earth is used to remove the green color of chlorophyl in some cooking oils. Syn., bleaching earth

blunger See blunging

blunging a processing term used in industry to describe the high-energy mixing or disaggregation of clay (or a similar substance) into water to form a uniform slurry (i.e., suspension or slip) for use in ceramics or paper making. A blunger usually consists of a round or octagonal tank with a mixer-impeller attrition blade. Post-blunging slurry processing may be performed to separate and concentrate the clay mineral phase or remove grit and heavy minerals, via wet sieve, hydrocyclone, flotation, gravity separation, chemical modification and/or magnetic separation. See suspension, grit

Born repulsion forces Born repulsion forces are described as a strong, short-range repulsion term for bond energy between two charged ions. Born repulsion forces arise when neighboring ions approach sufficiently close so that the electron clouds involving the inner electron orbitals begin to overlap, thereby forcing higher energy states owing to the Pauli exclusion principle. The term increases exponentially as orbital interpenetration increases with the decrease in interionic distance.

bottom ash the fused, amorphous, siliceous residue from burning coal in industrial burners. Crushed and sized bottom ash is used as an aggregate substitute in concrete and as a non-crystalline substitute for quartz sand in sand blasting. *Cf.*, fly ash

Bragg's law Bragg's law describes the condition for an X-ray reflection (i.e., constructive interference) for crystalline materials and is given as $n\lambda = 2d\sin\theta$, where n is the path difference between reflecting planes, which must be an integer for constructive interference, λ is the wavelength, d is the interplanar spacing, and θ is the glancing angle of incidence (reflection angle). In an X-ray diffraction experiment, the λ is known and is dependent on the X-ray source in use, θ is the measured quantity, and d is the parameter that is characteristic of the material under study. Thus, both n and d are unknowns. In practice, the order of the reflection n is fixed for the value of d for a specific plane hkl (and thus is included in the value) and, the use of d_{hkl} symbolizes this inter-relationship. Thus, the modified version of the Bragg equation is used in practice, which is given as: $\lambda = 2d_{hkl}\sin\theta$.

Bravais lattice one of 14 different types of space lattices (three dimensional arrays). The Bravais lattices are characterized by identipoints showing translational periodicity, and this periodicity can be used to define a (unit) cell. There are five basic lattice types [P, A (or B or C), F, I, and R]. When distributed over the crystal systems, the five basic types produce 14 space lattices. *Cf.*, identipoint, lattice, array

brick a construction material (usually red, yellow, or pastel in color, generally rectangular in shape) mainly composed of calcium silicate phases, after firing or drying clay. Recycled and milled bricks (brick-dust) are used as additives in the production of lime mortar.

brittle a descriptive term for tenacity where a mineral breaks easily with a lack of flexibility or elasticity

brittle mica a group name for platy phyllosilicates of 2:1 layer and a layer charge of ~ -2.0 per formula unit. Rieder et al. (1998) defines the brittle micas as having greater than 50% of the interlayer cations as divalent. Brittle micas do not have swelling capacity. Common divalent cations in the interlayer include Ca and Ba. The subgroups of the brittle micas are based on dioctahedral or trioctahedral character, and species within the subgroups are based on chemical composition. *Cf.,* mica, true mica, interlayer-deficient mica, group names

brucite sheet inappropriate usage for trioctahedral sheet. See trioctahedral sheet, interlayer material

Brunauer-Emmett-Teller (BET) for specific surface area analysis surface area determination by sorption analysis of non-polar gases, typically N_2 , on a solid, as calculated from the linear form of the BET equation (see Brunauer et al., 1938) for multi-layer gas adsorption on the surface of a sample of known weight. The technique requires removal of sorbed gases from the sample prior to BET analysis. Objections involving the use of BET analysis for clays containing H_2O include 1) platy surfaces of the phyllosilicate particles protect underlying adjacent surfaces from gas adsorption, and 2) interlayer regions may become inaccessible to N_2 owing to pretreatments that remove interlayer H_2O, which collapses any swelling clays present, and thus results may be affected by preparation techniques. It is commonly considered to measure external surface area and, as such, should not be used for total specific surface area or as an indicator of the amount of chemically accessible internal surface area.

bulk modulus a measure of the resistance of a material to external stress, in units of pressure (usually gigapascals), by fitting the incremental change in potential energy with incremental change in volume (e.g., Birch-Murnaghan equation of state). The bulk modulus is measured by experiments or by simulations and best describes isotropic materials. *Cf.*, elastic constant.

buoyant unit weight see unit weight, effective

c/f-related distribution Stoops and Jongerius (1975) differentiated five characteristic types (e.g., fabrics) of soil and palustrine deposits based on coarse (c) and fine (f) or clay particles: monic, gefuric, cithonic, enaulic, and porphyric. The c/f related distribution is therefore the relationship between ground mass (matrix) and a general framework of coarser components (e.g. grains, aggregates). The different descriptions of the classifications, however, are not mutually exclusive:

cithonic c/f-related distribution A distribution where fine-grained material forms a wrap over the coarser skeletal components. Any orientation of the clay particles in the wrap or cover are not considered important in the definition.

enaulic c/f-related distribution A distribution where there is a framework of grain-supported skeletal components with partial infillings of fine grained materials and pore spaces.

gefuric c/f-related distribution The distribution involves fine-grained material connecting coarser components, where coarse material is not in direct contact with other coarse components.

monic c/f-related distribution This distribution consists of predominantly one size group, including all ground mass, amorphous material or skeletal components.

porphyric c/f-related distribution The distribution of generally coarse components within a ground mass of fine-grained material.

C_2S see calcium silicate (CS) phases

C_3A see calcium silicate (CS) phases

C_3S see calcium silicate (CS) phases

calcan see cutan

calcine to heat a substance to a temperature where it dissociates, for example the heating of calcite ($CaCO_3$) to form CaO and CO_2. If clay is calcined, hydroxyl groups are removed from structural constituents and plasticity is destroyed.

calcium aluminate hydrate (CAH) phases CAH phases are widely used in the Portland cement industry to enhance the hardening effect of Portland cement. For example, "celite" ($Ca_3Al_2O_6$, "C_3A") is a non-hydrated calcium aluminate and a CAH phase, as is tetracalciuminate ($Ca_4Al_2O_7 \cdot 19H_2O$), a hydrated CAH phase. Lime (CaO) has been used for centuries as a stabilizer for soft clay treatment and improvement. It is generally believed that lime can slowly react with clay minerals to produce CSH and CAH phases that act as binders to contribute to the strength development of clayey soils. *Cf.*, calcium silicate hydrate (CSH) phases

calcium silicate hydrate (CSH) phases CSH phases are formed from calcium silicate (CS) phases [e.g., "alite" (Ca_3SiO_5, "C_3S"), "belite" (Ca_2SiO_4, "C_2S"), jennite ($Ca_9Si_6O_{18}(OH)_6 \cdot 8H_2O$) and tobermorite ($Ca_5Si_6O_{16}(OH)_2 \cdot 4H_2O$ or $Ca_5Si_6(O,OH)_{18} \cdot 5H_2O$)] by hydration, and these phases are responsible for the hardening effect of cement. Common CSH phases are calcium silicate hydrate (CSH) and ettringite ($Ca_6Al_2[(OH)_{12}(SO_4)_3] \cdot 26H_2O$). Lime (CaO) has been used for centuries as a stabilizer for soft clay treatment and improvement. It is generally believed that lime can slowly react with clay minerals to produce CSH and CAH phases that act as binders to contribute to the strength development of clayey soils. *Cf.*, calcium aluminate hydrate (CAH) phases, clinker, calcium silicate (CS) phases, hardening

calcium silicate (CS) phases Calcium silicate (CS) phases are common to clinker. CS phases are mainly formed by heating calcium carbonate (e.g., limestone for Ca) together with aluminum silicate (e.g., any available clay minerals for Si, Al) phases to temperatures to >1200°C. In practice, often marls, which are low in cost, are used as they combine carbonates and 2:1 layer phyllosilicates. Typical CS phases are "alite" (Ca_3SiO_5, "C_3S"), "belite" (Ca_2SiO_4, "C_2S"), or "celite" ($Ca_3Al_2O_6$, "C_3A"). These phases are responsible for the hardening effect of cement as they hydrate under the addition of water forming CSH phases. *Cf.*, calcium silicate hydrate (CSH) phases, clinker

Calgon® a commercial product consisting of sodium phosphate sometimes used as a dispersing agent for clays in aqueous suspensions. In this application, sodium phosphate buffers the solution and phosphate ions preferentially adsorb to clay edges. Both processes aid in dispersion of the clay. Calgon® is a registered trademark of The Calgon Corporation.

Carborundum® a commercial product composed of silicon carbide that is used as an abrasive in cutting, grinding and polishing applications. Carborundum® is a registered trademark of The Carborundum Corporation.

carrier solid fine to very fine-grained substances, e.g. clay minerals, with the following properties: 1. negligible dissolution within the active material, 2. able to bind the active substance by sorption, and 3. capable of releasing the active material under specific conditions. Smectite, talc, and other clay minerals are used as a drug carrier or a carrier for pesticides.

catalysis see catalyst

catalyst A catalyst is a substance that influences the rate of a chemical reaction without being consumed by the reaction. Catalysis is the process by which a catalyst influences a reaction, and this process often involves adsorption or the formation of intermediate compounds. When catalysis occurs, the overall Gibbs free energy of the reaction does not change.

cataplasm see poultice

cathode see electrode

cation see ion

cation exchange a process whereby a cation bound to a site on a surface is replaced by a cation from a solution. In both phyllosilicates and zeolites, the cation may be located on either external surfaces or internal surfaces; thus, the full process may involve cations from the interior that diffuse toward the surface, and are in turn replaced by cations from the solution which diffuse inward. The term differs from solid-state diffusion primarily by time scale, where cation exchange occurs relatively quickly and solid-state diffusion requires a much longer period.

cation-exchange capacity (or CEC) the surface charge of a phyllosilicate that relates to a net negative imbalance of charges originating from the silicate layers of the mineral. The magnitude or capacity for exchange (see cation exchange) is related to the size of the net negative charge that occurs within the (commonly, 2:1) layer. Cation exchange occurs where a solution containing the exchangeable cations forms a concentration gradient with the exchangeable cation of the mineral. The charge on the mineral is operationally related to the magnitude of the number of exchanged cations. The net negative charge is considered "permanent charge", and this originates from either (or both) tetrahedral or octahedral solid solutions, changes in oxidation state of constituent cations in the layer, substitutions involving anions [e.g., O2- for (OH)-], and other possible factors.

celite see calcium silicate (CS) phases

cell parameters The cell parameters define the edges of the smallest repeating parallelepiped of the atomic arrangement of a crystal. Values of the cell parameters are usually given as three scalar cell lengths (*a*, *b*, *c*) and three angles alpha (between *b* and *c*), beta (between *a* and *c*), and gamma (between *a* and *b*). *Cf.*, unit cell.

Celsius A temperature scale based on a degree, ºC, where the freezing point of pure water at one standard atmosphere is arbitrarily set at 0 and the boiling point at 100 ºC. One Celsius degree equals one Kelvin. 0 ºC equals 273.15 K. *Syn*., centigrade *Cf.*, Fahrenheit, Kelvin

cement a solid binding agent between grains/particles of natural rocks (e.g., sandstones), soils, or synthetic construction materials (e.g., geopolymer, Portland cement, concrete). *Cf.*, binder

cementation the process of forming the mineral matter that binds particles of a sedimentary rock together. The cementation process usually involves a chemical precipitate from solutions that may originate within the sediment or from outside the sediment body. The mineral matter is called "cement". In general terms, the stiffness and strength of the sediment or soil is increased by the mineral matter. The mineral matter is often clay minerals, oxides, silica, carbonates, sulfides and others.

center of symmetry symmetry involving a repetition of identical features about a point at the center of the object. Thus, any point in the object will have a corresponding point (to produce an inversion) repeated an equal distance from the object's center along a line established by the original point and the center point of the object. Also known as an "inversion center". *Cf.*, symmetry, mirror plane, rotation symmetry, rotoinversion

centigrade see Celsius

centripetal replacement Alteration that occurs from a grain boundary inward or from internal fractures within a grain toward the center of the grain. Centripetal replacement is often recognized by texture, especially if alteration is incomplete. *Cf.*, alteromorph, peripheral replacement, pseudomorph

ceramic a fine-grained inorganic solid produced by mixing milled raw materials with appropriate amounts of water, molding or shaping to obtain a green body (weakly bound solid mass), which is dried at room temperature, and then fired at temperatures >800°C. Firing temperatures >1200°C or glazes may be used to reduce the porosity to obtain watertight ceramics (e.g., for vases). Different raw materials can be used, depending on the type of ceramic to be produced. Clay (e.g., kaolin, bentonite), with marl, loam, feldspar, quartz, and lime are used for silicate ceramics (e.g., for bricks, clinker, or porcelain). Oxides Al_2O_3, ZrO_2, TiO_2, and Al_2TiO_5 are used for oxide ceramics (e.g., in car tires to reduce the rolling resistance, in blast furnace construction), and carbides SiC, BN, B_4C, Si_3N_4, or WC are used for non-oxide ceramics for plain bearing and soot particle filter in cars). Besides chemical and mineralogical differences, ceramic is often classified based on its porosity, which is determined by firing temperature. The most porous earthenware, (e.g., for flower pots) is fired between 950 - 1100˚C, stoneware (e.g., for bottles, vases, tableware), is less porous and is fired between 1100 - 1300˚C, and porcelain (e.g., for fine tableware) is the least porous due to its high firing temperature up to 1400˚C.. Pottery is a more general term for ceramic material fired above 400°C. The word ceramic is derived from the Greek word "keramos", which means burned clay. *Cf.*, brick, clay, clinker, earthenware, glaze, green body, porcelain

cetyltrimethylammonium organoclay see hexadecyltrimethylammonium organoclay

Chambers-type montmorillonite A now-obsolete term first used by Schultz (1969) to define montmorillonite samples on the basis of chemical and thermal analysis with a total net layer charge of -0.85 to -1.20 per unit cell $[O_{20}(OH)_4]$, with a layer-charge contribution from tetrahedral substitutions of between -0.15 to -0.50, although exceptions were noted. See Tatatila-type montmorillonite. Terms used in this obsolete classification are: Wyoming-type, Otay-type, Chambers-type, Tatatila-type, beidellite-type (ideal and non-ideal), and non-ideal montmorillonite. Current nomenclature for montmorillonite is that it is an Al-rich, dioctahedral smectite with an ideal structural formula of $(Al_{3.15}Mg_{0.85})Si_8O_{20}(OH)_4X_{0.85}.nH_2O$ with layer charge from primarily octahedral substitutions of Mg. See also Part 2 of the Glossary.

chamotte a ceramic raw material with a high silica and alumina composition typically produced by firing selected "fire clays" to high temperatures before grinding and screening to specific particle sizes. Chamotte is usually porous with a low bulk density. *Cf.*, fire clay

chemical equilibrium the state in which the rates of forward and reverse reactions are equal; thus, at equilibrium, the change in free energy $\Delta G = 0$

chemical weathering the process whereby chemical reactions alter or break down minerals or rocks under the influence of meteoric water at or near the Earth's surface. Specific chemical weathering reactions include, but are not limited to, dissolution (congruent or incongruent), oxidation, hydrolysis, cation exchange, complexation, hydration, carbonation, and sulfation. Chemical weathering may be biologically influenced. See weathering, physical weathering

chemical kinetics the study of reaction rates and mechanisms

chemical thermodynamics see thermodynamics

chemical potential a thermodynamic term for the change of the Gibbs free energy of a system with respect to the change in the number of moles of a specific constituent. Chemical potential is equivalent to partial molar enthalpy, partial molar free energy, partial molar internal energy, and partial molar Helmholtz function. The chemical potential may be described as a force of energy change caused by a change of composition.

chemically activated clay a clay treated with chemical substances to improve properties or to increase reactivity. Chemical activation includes alkaline and acid activation. *Cf.*, acid activated clay, alkaline activated clay

China clay Porcelain was first made in China using kaolin, feldspar, and quartz. Traders brought porcelain back to Europe and when porcelain was made in Meissen, Germany and in England, the primary kaolin used in the formulation was called "China Clay". The term is still used today largely in Europe and is synonymous with kaolin.

chlorite a group name for platy phyllosilicates of 2:1 layer with a variable layer charge. The interlayer material consists of a hydroxide octahedral sheet, which results in $d(001)$ value of approximately ~ 14.0-14.4 Å. The group is further divided into subgroups that are either trioctahedral or dioctahedral, and these subgroups are further divided into mineral species based on chemical composition. See further explanation under "group names". See also Part 2 of the Glossary.

cicatrizers substances that close a wound by scar formation; substances that heal (e.g., by healing clays). *Syn*., cicatrize

***cis*-vacant** a dioctahedral phyllosilicate where the vacancy is ordered and occurs in the octahedral site where the OH,F anions reside on adjacent corners of the octahedron (i.e., *cis* orientation). Alternatively, the description of the *cis* site is off the mirror plane (based on the idealized layer symmetry, not necessarily the structure in its entirety) of the layer. *Cf.*, *trans*-vacant

cithonic c/f-related distribution see c/f-related distribution

clay suspension see suspension

clay a naturally occurring material composed primarily of fine-grained minerals, which is generally plastic at appropriate water contents and will harden when dried or fired. Although clay usually contains phyllosilicates, it may contain other materials that impart plasticity and harden when dried or fired. Associated phases in clay may include materials that do not impart plasticity and organic matter. Different disciplines have uniquely defined the size of clay particles, and it is for this reason that "fine grained" is used in the definition rather than a precise value. However, because of these size variations from discipline to discipline, it is important that the particle size be specified in the context of the application. (*Quot* Guggenheim and Martin, 1995). For definitions relating to non-clay-science applications, see Jackson (1997).

clay birefringent fabric Clay birefringent fabric is a petrographic feature showing the development of oriented, "bright" clay fabrics in the groundmass. These high birefringence regions under crossed polarizers are composites of many parallel clay particles that act together to produce a cohesive pattern. In sediments and soils, clay birefringent fabrics are commonly associated with bioturbation and wetting-desiccation cycles, respectively. See fabric.

clay groundmass a general petrographic term for a fine-grained (clay size) material between coarser particles and pedofeatures in sediments or soils. The term groundmass in soils is analogous to matrix in sediments and sedimentary rocks. *Syn.* soil plasma, pedoplasma.

clay mineral refers to phyllosilicate minerals and to minerals which impart plasticity to clay and which harden upon drying or firing. This definition expands the previous definition of Brindley and Pedro (1972) by relating clay minerals to the properties of clays. Clay minerals may be of any crystallite size so that the term "clay mineral" is consistent with the definition of "mineral", which is unrelated to crystallite size. (*Quot* Guggenheim and Martin, 1995). However, the unique properties of clays are partly related to their small particle size and high surface area (Guggenheim and Martin, 1996). *Cf.*, clay, phyllosilicate, mineral

clay nanocomposite a nanocomposite (i.e., fine-particulate material that is heterogeneous at the nanoscale level, at less than 10^{-7} meters) where one or more of the constituent fine-particulate materials are clay minerals. Other parts of the composite may be, for example, polymers, which act as the dispersant. Some clay composites are fabricated with the polymer both around the clay particle and in the interlayer between the 2:1 or 1:1 layers. *Cf.*, nanocomposite

clay solution or **sol** see suspension

clay slickenside In geology, slickenside is a field term for striated and polished surfaces on a fault plane, which can often indicate the direction of fault movement. A clay slickenside is where the groundmass constituents, mostly clay, have been rearranged so that the platy particulates parallel the surface. In clay science, the term "slickenside" is used also for the natural crack surfaces that are polished, but produced by swelling and shrinkage in smectite-rich soils. In soil science, clay slickensides are a diagnostic feature of Vertisols, which are clayey high shrink/swell soils. The shrink/swell action "inverts" or mixes the upper parts of the soil because organic-rich surface material falls into cracks during dry periods.

clay-organic complex see organoclay

clay-polymer nanocomposite see clay nanocomposite

clayshale An indurated, fine-grained sedimentary rock composed of >66% clay-sized constituents with lamination (stratification of <10 mm thickness), after Potter et al. (2005). See clay, claystone, mud, mudrock, mudshale, mudstone, silt, siltstone.

claystone A fine-grained sedimentary rock having >66% clay-size constituents and little or no sand, with stratification (i.e., bedding) of >10 mm thickness. Bedding within the claystone may be massive (after Potter et al., 2005). See clay, clayshale, mud, mudrock, mudshale, mudstone, silt, siltstone.

cleavage The tendency of a crystal to break along certain (and generally smooth) planes of weakness. Planes of weakness in a crystal usually reflect either the presence of a plane of weaker or fewer bonds in a structure, and thus cleavage is a diagnostic property. These planes can be described as Miller indices, and are thus rational. *Cf.*, parting

clinker a) Clinker, in materials science, is a sinter product of limestone and clay (or other secondary raw materials such as fly ash, sand, or slag) heated in kilns. Clinker is used as the primary component for Portland cement and is typically composed of calcium silicate (CS) phases such as "alite" (Ca_3SiO_5, "C_3S"), "belite" (Ca_2SiO_4, "C_2S"), or "celite" ($Ca_3Al_2O_6$, "C_3A"). b) Clinker, in geological sciences, refers to a sedimentary bed that has undergone combustion, such as a coal bed that has undergone combustion and alteration by an igneous intrusion or by a coal-bed fire. Clinker may also refer to a pyroclastic or lava mass that resembles furnace slag. *Cf.*, calcium silicate phases; fly ash; slag, blast-furnace; kiln, rotary; Portland cement.

closure see rotation symmetry

clumping clay A commercial-grade clumping clay is a clay where coherent clumps, capable of easy removal from a liter box, form from exposure to cat urine. Commercial clumping clays have added hydrophilic polymers to improve coherency and strength of the resultant clumps. The addition of these polymers is to address the problem of very concentrated urine in some cats, especially male cats, where the salt concentrations are very high. Manufacturers in the U.S. commonly use Na-rich montmorillonite from Wyoming and South Dakota as clumping clays.

coagulation See flocculation

co-ion an ion with a charge of the same sign as the charge of the solid interface. *Cf.*, counter ion

co-precipitation an occurrence of a solid phase precipitate along with other components from solution. The mineral sorbent may partially or completely dissolve or the solution may become oversaturated with respect to a phase so that components may re-precipitate along with other components from solution.

coalescence The process of coarsening of particles from a thermodynamically unstable dispersion. The total surface area is reduced.

coarse ware a primitive style of ceramic with rough surfaces, e.g., roofing tiles, ceiling tiles, cooking vessels. This kind of ceramic was common for everyday items in ancient periods (e.g., Roman, early Egyptian, prehistoric) *Cf.*, pottery, ceramic, white wear.

coating In soil science, a coating is a layer of material, such as clay, organic material, mineral, non-crystalline material, etc., that partially or completely covers soil components (e.g., grains, voids). The term excludes b-fabrics. *Syn.*, cutan; *Cf.*, hypo-coating

cohesion Cohesion refers to the attractive forces (e.g., van der Waals, Coulombic) between two molecules of the same kind or two surfaces of similar material. For example, the shear strength of wet clayey soils involves both cohesive forces and friction. For wet clayey soils, the cohesion component of shear strength primarily results from the surface interactions between two clay particles (of similar composition and structure). *Cf.*, adhesion

colloid an entity, either a solid or a liquid, dispersed in a medium. The entity must have one of its dimensions between 1 nm and 1 µm. A colloid dispersed in a liquid is also termed a "sol". The term may be used also for the system as a whole. (after Lyklema 1991). See gelling clay.

colloidal suspension see suspension

commensurate the relationship where a superstructure (or superlattice) is equal to an integral number of subcells (or sublattices). For example, some crystals of antigorite exist where the substructure *a*-cell dimension is 5.4 Å, and the superstructure of 32.4 Å, occurs from a wave-like curvature of the 1:1 along the [100] direction. Because the superstructure is 6 x 5.4 Å = 32.4 Å, the superstructure is commensurate with the substructure. In other crystals of antigorite, the superstructure may be related to the substructure by a non-integer number of subcells, and this is referred to as a non-commensurate relationship.

colloidal solution see suspension

commensurate the relationship where a superstructure (or superlattice) is equal to an integral number of subcells (or sublattices). For example, some crystals of antigorite exist where the substructure *a*-cell dimension is 5.4 Å, and the superstructure of 32.4 Å (6 x 5.4 Å), occurs from a wave-like curvature of the 1:1 layers along the [100] direction. Because the superstructure is a multiple of the subcell dimension, the superstructure is commensurate with the substructure. In other crystals of antigorite, the superstructure may be related to the substructure by a non-integer number of subcells, and this is referred to as an incommensurate or non-commensurate relationship.

compact see cryptocrystalline

compaction a) In geology, compaction (= geological compaction) refers to the densification process caused by the gradual increase of overburden (weight) resulting from continuous deposition of sediments or by pressures from the movement of rock within the crust. b) The geologic process of changing fine-grained sediment to consolidated rock, as in clay to shale. c) In soils engineering, compaction is the artificial process to improve the engineering properties of a clay or soil by mechanical energy (e.g., vibration, static pressure). The clay or soil is usually partially saturated and thus contains mineral particles, air, and water. Compaction reduces the volume of air in the pores so that the dry density of the soil/clay increases. In practice, to maximize compaction, the water content is adjusted to a suitable value, called the optimal water content, so that the dry density approaches a maximum value. See water, optimal content for compaction; consolidation, clay or soil

complex A complex is a dissolved or surface species that forms by association of a cation and either an anion or a neutral molecule, the latter anion or molecule is often referred to as a ligand. The complex may have an overall charge that is positive, negative, or neutral.

compressibility a) In soils engineering, compressibility is a mechanical property that defines the resistance of a water saturated clayey soil to compressional deformation under effective stress. The change in effective stress leads to the flow of porewater, resulting in the change in soil thickness or volume. Usually the compressibility of clay is measured by the one-dimensional (i.e., K0 condition) consolidation testing, and is defined by the compression index. b) In geophysics, compressibility is defined as the reciprocal of the bulk modulus, which relates the change in volume of a material to the hydrostatic state of stress. See also effective stress, void ratio, compression index

compression, secondary the stage of consolidation compression occurring under constant effective stress after primary compression, where a change in effective stress occurs. *Syn*., drained creep; *Cf*., compression, primary; creep.

compression, secondary The stage of consolidation compression occurring under an effective stress imposed after primary compression. Whereas primary compression or consolidation is mainly caused by the escape of excess pore water pressure accompanied by the change in effective stress, secondary compression occurs only under a constant effective stress. *Syn*., drained creep; *Cf*., compression, primary; creep.

compression index the ratio of change in void ratio to the change in the logarithmic effective stress when a clay is subject to consolidation. *Cf*., compressibility

compression, primary In clay science, the initial stage of consolidation compression of a clay, which is governed by the dissipation of excess pore water pressure (i.e., pore water pressure in excess of the hydrostatic water pressure). During this stage, the excess pore water pressure changes (usually approaching the hydrostatic water pressure), and the clay either produces pore water (in the case of positive excess water pressure) or adsorbs water into the pores (in the case of negative excess water pressure). During this stage, the effective stress changes, and the clay volume changes as well. *Cf*., compression, secondary

compressive strength a material property commonly determined for cements (e.g., Portland cements, also geopolymers) to evaluate their resistance to compression by a load. The compressive strength is given as the applied force at the point of failure (in Newton, N), usually at the peak force, divided by the initial area over which the force was applied (in m^2). Compressive strength is measured from the amount of stress (force) that is gradually increased until the structure of the material is unable to absorb any more energy, leading to fractures, brittle failure, or excessive plastic deformation. *Cf*., Portland cement, geopolymer

concrete a building material comprised of a binder (e.g., cement, Portland cement) and aggregates (e.g., sand, gravel, crushed stone). With the addition of water to the dry binder, a hydraulic reaction causes calcium silicate hydrate (CSH) phases to form. This process is called setting or hardening and leads to the strength of the cement/concrete. *Cf*., calcium silicate hydrate (CSH) phases, Portland cement, cement

concretion see glaebule

conditional stability constant although not a true equilibrium constant, a conditional stability constant describes the equilibria of complex formation at ambient solution conditions. For example, a conditional stability constant may be used when pH is fixed at a specific value; the conditional stability constant would then vary with pH. Thus, the complex will be either strong or weak depending on solution conditions, in this case with pH and possible protonation of the ligand. In other cases, temperature or ionic strength may alter metal to ligand strength, which changes the conditional stability constant. Conditional stability constants are commonly used to describe surface complexation reactions. *Syn.*, apparent stability constant; See also ligand

congruent dissolution Congruent dissolution is where the same ratio of atoms present in the parent phase is released to the solution. This type of dissolution may be referred to as "stoichiometric" dissolution. *Cf.*, congruent melting, incongruent dissolution, incongruent melting

congruent melting Upon heating to form a liquid, the liquid (melt) has the same composition as the solid. *Cf.*, congruent dissolution, incongruent dissolution, incongruent melting

consolidation, clay or soil the process by which a clay unit deforms as a result of drainage of pore water with non-equilibrium pressure produced by loading. During consolidation loading, the positive non-equilibrium pore water pressure causes water to flow out of the soil, resulting in a decrease in soil volume, also called consolidation settlement. The process of consolidation is usually accompanied by an increase in effective stress. This is different from drained shearing. In general, the loading rate for consolidation must be much smaller than drained shearing. *Cf.*, drained shearing, effective stress

consolidation loading see consolidation, clay or soil

consolidation settlement see consolidation, clay or soil

constrained polymer region For polymer nanocomposites, the volume around nanoparticles where the degree of freedom of movement of the polymer has been lowered. This region involves the interaction between the polymer and nanoparticle and is distinguished by having properties that are different from the bulk polymer properties. The volume of this region is dependent upon the strength of the interaction of the polymer and nanoparticle and the flexibility of the polymer. The concept, for example, explains why a gas diffusion coefficient of a polymer nanocomposite may differ from the bulk polymer. Gas diffusion may also be affected by the arrangement of clay particles that leads to a "tortuous path" and a reduction of diffusion through the nanocomposite.

continuously stirred tank reactor (CSTR) a reaction vessel with inlet and outlet flow and whose contents are stirred. CSTRs are commonly operated at steady state, but they may alos function transiently. *Cf.*, batch reactor, chemostat, plug flow reactor

contraction, soil or sand In soil science, soil or sand contraction involves the volumetric reduction of a saturated clayey soil or sand body by drained shearing. For a soft, normally consolidated or lightly over consolidated saturated clayey soil subject to drained shearing, pore water generally flows out of the soil (or sand) owing to shearing-induced positive excess pore water pressure, and hence its total volume decreases, indicative of contraction behavior. *Cf.*, dilation

converse piezoelectric, see piezoelectric

cosmetics The United States Federal Food, Drug, and Cosmetic Act (FD&C Act) of 13 March 2013 defines cosmetics by their intended use, as "articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body...for cleansing, beautifying, promoting attractiveness, or altering the appearance" [FD&C Act, sec. 201(i)]. The act specifically excludes soap as a cosmetic. Clays and clay minerals used in cosmetics include bentonite, illite, kaolin, iron oxides, etc., often characterized by color or locality, and each purported to function or behave differently.

Coulomb interactions For classical calculations or simulations of atomic structures, Coulomb interactions account for the attraction or repulsion between pairs of atoms in accord with the positive or negative charge on each atom. Coulomb's Law is used to calculate the potential energy between each pair of atoms in the model system. For periodic systems, the long-range component of these interactions is often treated in reciprocal space by Ewald summation or a similar technique. *Syn*., Coulombic interactions, electrostatic interactions; *Cf.*, Ewald sum, force field

counter ion an ion with a charge opposite in sign to the charge of the solid interface to which it is attracted. *Cf.*, co-ion

covalent bond a chemical bond that involves sharing of one or more electrons, generally an electron pair. Covalent bonds require the appropriate geometric arrangement of coordinating atoms so that orbitals can overlap. Diamond, which involves carbon atoms, exhibits the ideal characteristics of covalent bonds. However, many elemental pairs involve covalent character and other bonding character (i.e., covalent plus ionic character as in the Si-O bond).

creep a) In soil mechanics or geotechnical engineering, creep refers to the process of slow deformation of saturated material occurring under a constant effective stress, usually after the deformation in response to loading and/or to pore water pressure changes. For clays, if the pore water in the clay is allowed to escape, then the process is drained creep; if the pore water of the clay is confined, then it is undrained creep. b) In geological sciences, creep is the very slow downslope movement of material. *Cf.*, secondary compression.

critical radius In crystal growth and heterogeneous geochemical kinetics theory, the "critical radius" refers to the smallest size that atoms or ions must come together to produce a stable nucleus for crystal growth or to allow bubbles to form.

cross striated b-fabric see b-fabric

critical state a) In physics, the critical state (or critical point) is where a substance has two physical states) with the same temperature, pressure and volume. For example, it is where a liquid and gas phase of a substance cannot be differentiated because the volume is the same at a fixed temperature and pressure. The critical state for water occurs at 374 ^{o}C at 218 bars, and the liquid state cannot be differentiated from steam. b) In soil science, the critical state is where the shear stress remains at a constant value (i.e., steady) while the shear strain continues to increase, when a fully saturated clayey soil or sand body is subject to a relatively large shear strain. If the shearing process is drained, the total volume also remains constant. *Syn*., constant volume state

crossed polars see petrographic microscope, crossed polarizers, crossed nicols

crossed polarizers "Polars" or "polarizers" are devices that permit passage of light with vibrations in only one direction. In an optical "polarizing microscope", two polarizers (the lower device is often referred to as the "polarizer" and the upper device is the "analyzer") are oriented such that light vibrations are at 90 degrees from each other (and the two polarizers are said to be "crossed"). If nothing is present in the optical path between the two devices to change the light vibrations, all light is prevented from passing and the image is black. Material placed in the optical path changes the behavior of the light rays, with the behavior dependent on the crystallography of the material (e.g., crystal structure, crystallinity), the chemical composition, the thickness of the material, and refractive indices. If the analyzer is removed from the optical path, then the devices are not considered "crossed". *Syn*., crossed nicols, crossed polars

crossed nicols (archaic) The original polarizing prisms of petrographic microscopes were the early 19th century design of William Nicol, and each was referred to as a Nicol prism (Bloss, 1961). When both Nicol prisms were introduced into the optic path in mutually perpendicular orientations, the examination was said to be using "crossed Nicols". The phrase "crossed nicols" is still used for this geometry of polarized light, regardless of whether the polarizing optics use Nicol prisms or another polarization device. See petrographic microscope, crossed polarizers

cryptocrystalline a rock-texture term for which the individual mineral grains in an aggregate are too small to be distinguished in an ordinary light microscope. If grains can be distinguished in a light microscope, the texture is "microcrystalline". The rock is said to have a "compact" texture if grains cannot be distinguished by the naked eye. Carbonate petrographers use a discrete crystal dimension for individual carbonate grains for a rock to be classified as having "cryptocrystalline" texture, although the dimension does not appear to be in universal agreement.

crystal growth, driving force In thermodynamics, the driving force (F_d) associated with crystal growth is: $F_d = \Delta\mu/k_BT = \sigma$, where $\Delta\mu$ is the change in chemical potential, σ is the supersaturation state, k_B is the Boltzmann constant, and T is absolute temperature.

crystal chemistry Crystal chemistry is the study of the solid state with the associated principles and interpretation of atomic structure and related chemical and physical properties (or any structure-property relation). Systematic crystal chemistry is the study of how the atomic structure relates to changes in the composition, environmental conditions, and physical properties of a solid. Originally, crystal chemistry related to crystalline solids only, but amorphous or near amorphous states may be described using similar principles.

crystal structure the atomic arrangement for a crystalline material

crystal class see point group

crystal an element or chemical compound that is crystalline and shows planar faces that express this crystallinity. If the solid lacks faces, it is referred to as "anhedral" and if it is completely bounded by faces, then it is referred to as "euhedral", and it is "subhedral" if bounded by poorly defined faces. The term "single crystal" is often used in a colloquial sense for crystalline grains which are anhedral.

crystal system Crystal systems are defined based on the symmetry of a crystal. There are six crystal systems, given in decreasing symmetry: cubic (or isometric), hexagonal, tetragonal, orthorhombic, monoclinic, and triclinic. Minimum symmetry requirements are: four 3-fold or -3 axes (cubic), one 3- or 6-fold axes (hexagonal), one 4-fold axis (tetragonal), three mutually perpendicular directions with 2-fold and/or mirror plane symmetries (orthorhombic), one 2-fold axis and/or mirror plane (monoclinic), and center of symmetry or identity operation only (triclinic). Consequently, because of the symmetry present, the relative lengths of the crystallographic axes and the values of interaxial angles may be constrained: cubic, $a_1 = a_2 = a_3$, $\alpha = \beta = \gamma = 90$ °; hexagonal, $a_1 = a_2 = a_3$ not equal c, α, $\beta = 90$ °, $\gamma = 120$ °, $\beta = 90$ °; tetragonal, $a_1 = a_2$ not equal c, $\alpha = \beta = \gamma = 90$ °; orthorhombic, a not equal b not equal c, $\alpha = \beta = \gamma = 90$ °; monoclinic, a not equal b not equal c, $\alpha = \gamma = 90$ °, $\beta > 90$ °; triclinic, a not equal b not equal c, α not equal β not equal γ. The term "isometric" is sometimes used as a morphological term where the measured crystal is equant. *Cf.*, crystallographic axes

crystalline a solid consisting of atoms, ions, or molecules packed together in a periodic arrangement. The material must have sufficient atomic ordering such that a (X-ray, electron, neutron, etc.) diffraction pattern containing well-defined maxima can be indexed using Miller indices (Nickel, 1995). *Cf.*, non-crystalline

crystallinity index an attempt to describe the state of crystallinity of a solid as a value of some characteristic, usually relating to diffraction. The term is a misnomer because it suggests that the complex idea of crystallinity may be represented by a single value. The use of the term "crystallinity index" should be avoided, although it may be placed within quotation marks when referring in a limited way to previously referenced work (Guggenheim *et al.,* 2002). Some indices are useful to describe e.g., crystallite size or grade of diagenesis. Indices were derived by Hinckley (1963) to distinguish between different samples of kaolinite, by Kübler (1964) to describe certain origins of samples of illite, and by Árkai (1991) to describe different origins of chlorite. It is recommended to refer to the author describing the procedures necessary to define the value, regardless of what the index may actually be describing, such as the Hinckley index.

See Guggenheim *et al.* (2002) and references therein. *Cf.*, Árkai index, Kübler index, Hinckley index

crystallographic axes a set of reference axes used in crystallography. These axes are usually three in number, although in some cases, they may be four. The axes are generally mutually perpendicular, coincide with symmetry axes or the normals to symmetry planes, and in cases where the crystal lacks symmetry, parallel to lines of intersection of two faces with greatest areas. These axes are designated as *a*, *b*, *c*, and angles between axes are designated α, β, and γ where α is located between axes *b* and *c*, β is located between axes *a* and *c*, etc. according to the right-hand rule. See also: crystal system.

CSTR see continuously stirred tank reactor

cubic see crystal system

Curie temperature see ferromagnetism, ferroelectric

cutan A pedofeature involving material (commonly oriented clay coatings, but also gels, amorphous, etc. coatings) that covers the surfaces of voids, grains, and aggregates, and are common in paleosols. Cutans may be derived and differentiated as diffusion cutans, illuviation cutans, and stress cutans. Other cutans may describe compositional variations. Cutans may be identified in a paleosol or soil under the optical microscope. See pedofeature.

argillan an (oriented) clay coating over grains, voids, or aggregates. Compositional characteristics may be used as prefex modifiers, as "ferri-argilan" (iron oxide stained) or "organo-argillan" (stained by organic matter). See cutan, pedofeature, ferran, mangan. *Syn.*, clay skin.
calcan a cutan composed of calcite.
ferran a cutan of iron oxide and hydroxide
mangan a cutan of manganese oxide and hydroxide
organan a cutan composed of organic matter
silan a cutan formed of opal or chalcedony
sesquan a cutan composed of Al-Fe oxides
soluan a cutan of soluble salts (e.g. gypsum)

***d* value** As defined in the Bragg equation for diffraction, $n\lambda = 2d \text{Sin}\theta$, where n is an integer, λ is the wavelength, θ is the glancing angle of incidence, and d is the (perpendicular) spacing between the diffracting planes. Because d is defined as a spacing, the term *d* spacing is redundant. See Bragg equation

***d* spacing** see *d* value

Debye length see diffuse double layer

deflocculant a substance that disperses particles to form a colloidal or near-colloidal suspension when added to a slurry that contains clumps of particles that have aggregated to form larger non-fused particles. Common deflocculants for simple (non-exchanged) clay systems include sodium carbonate or sodium phosphates, such as sodium pyrophosphate. These deflocculants produce a buffered, high pH solution and are especially useful when size-separating clay particles. *Cf.* flocculation.

deflocculate to disperse clumps of small particles adhering together in a suspension to form a colloid or near-colloid suspension. The resulting suspension is more fluid than the original.

dehydration the removal of H_2O from a phase. The H_2O may be present as an integral part of the atomic structure or as "free" (adsorbed) water. Dehydration commonly is achieved by heating or by evaporation.

dehydroxylate any phase obtained by elimination of the hydroxyl from phyllosilicates prior to recrystallization. (*Quot* Guggenheim *et al.,* 2006)

dehydroxylation the removal of $(OH)^-$ groups from the atomic structure of a phase. Decomposition/recrystallization usually results, but there are some materials that form dehydroxylate structures prior to recrystallization. *Cf.,* dehydroxylate, rehydroxylation

delamination Delamination is a term used to describe a layer-separation process between the planar faces of adjacent layers of a particle. Delamination describes a process whereby intercalation occurs with the introduction of guest material and the stacking of layers remains. This term differs from exfoliation. Exfoliation implies that the orientation between the layers of the host structure is lost, and that interlayer cohesive forces are overcome. Where delamination or exfoliation cannot be distinguished, use "intercalation" or "delamination/exfoliation" to describe the process. See intercalation, exfoliation, 1:1 layers, 2:1 layers. (From AIPEA Nomenclature Committee, 2011, unpublished)

density functional theory (DFT) an approximate method of incorporating quantum mechanics in calculating the electronic structure and related properties of a finite or periodic molecular model. This method differs from *ab initio* methods (*i.e.*, a first principles method typically using a molecular orbital model) in that electron-electron interactions are approximated using functional mathematics in vector space. *Cf.*, molecular dynamics, quantum calculation

devitrification crystallization from a glass

deposits, eluvial In geology, sedimentary deposits (or eluvium) derived by weathering, either with or without significant movement by the effects of gravity. In soil science, a soil horizon developed by the removal of soil material in suspension or solution (leaching) from a layer of a soil.

deviator stress The deviator stress is the difference between the major principal stress (σ_1) and minor principal stress (σ_3). The deviator stress usually defines the shear resistance of a clayey soil under triaxial shear loading.

DFT see density functional theory

diagenesis the chemical, physical, and biological reactions incurred by sediment during burial, after initial accumulation. Diagenesis reactions may involve addition and removal of material, transformation by dissolution and recrystallization or replacement (authigenesis), or both, and phase changes (See *Ostwald ripening*). Weathering, incurred by sediments at the Earth's surface under ambient conditions, is not part of the diagenesis process and represents the lower temperature limit of diagenesis. Hydrothermal, geothermal, and contact metamorphism are not considered part of the diagenesis process. The lowest grade of metamorphism limits the diagenesis process at high temperature and high pressure. In clay-rich rocks, the boundary between diagenesis and very low-grade metamorphism (anchizone is the transitional zone) has a Kübler index of 0.42 - 0.25 degrees two theta. Reduction of smectite interlayers in illite-smectite interstratifications to <10% is typical of the diagenetic zone-anchizone transformation (Merriman and Peacor, 1999). Weaver and Brockstra (1984) proposed a boundary between diagenesis and metamorphism as that point at which disordered illite ($1M_d$) has been converted to ordered ($1M$, $3T$ or $2M_1$). "Retrograde" diagenesis was described by Nieto et al. (2005) as "fluid-mediated retrograde processes occurring under diagenetic conditions". See anchizone, epizone, interstratification, Ostwald ripening, smectite-illite *Cf.*, Kübler index

diamagnetism describes a property of material where there is repulsion by a magnet. *Cf.*, magnetic susceptibility, magnetism

diatomaceous earth a soft, naturally occurring, sedimentary rock, of marine or freshwater origin, composed of biogenic silica derived from tests (shells) of single-celled algea (diatoms). Diatomaceous earth has a high melting point (1715 °C) and is used in filters, mild abrasives, thermal insulators, and absorbants. *Syn.,* diatomite

diatomite see diatomaceous earth

dielectric see insulator

diffuse layer see diffuse double layer, Stern layer

diffuse double layer All surface charges are balanced by oppositely charged counter ions. Some of these counter ions are bound, usually transiently (see cation exchange), in the so-called Stern or Helmholtz layer, some of them may diffuse away from the surface and form a diffuse layer. Both the charged surface and the diffuse ions form the electric double layer, which in total is uncharged. The thickness of the diffuse layer is solely a function of the ionic strength of the solution. The distance 1/kappa, where the thickness has decreased to roughly 1/e is called the

Debye (screening) length. The thickness decreases with increasing ionic strength because of the screening effect of ions. *Cf.*, Stern layer

diffusion the process of mass transfer of matter from areas of high activity to low activity, or of energy where heat is transferred from higher temperatures to regions of lower temperature, over time. Diffusion is generally driven by thermal vibration of the mass.

diffusion, volume the temperature dependent process of mass transfer of matter in solids from areas of high concentration to low concentration. Volume diffusion commonly occurs along interstitial channels or grain boundaries, or by vacancy exchange with an atom, ion, or molecule. See diffusion.

dilatancy a) a property of a non-Newtonian fluid where the viscosity of the fluid increases sharply at high shear rates but is constant for constant shear rates. The viscosity is reduced again if not agitated (e.g., stirred). *Cf.*, Newtonian fluid, quick clay, thixotropy, rheopexy b) In soil mechanics, dilatancy refers to the volumetric increase (i.e., dilation) behavior or property of a clay subject to drained shearing at or near the peak shear stress. A dense soil (e.g., dense sand, overconsolidated clay) exhibits volume expansion (i.e., the soil takes water into its void space) if sheared with drainage allowed, or reduced porewater pressure (i.e., a tendency for volume expansion or dilation) if sheared without drainage allowed. Usually maximum dilation rate corresponds to the peak shear stress or failure strength. *Cf.*, drained shear, undrained shear; dilation; contraction

dilation, soil or sand In soil science, soil or sand dilation involves the volumetric expansion of a saturated clayey soil or sand body when subject to drained shearing. For a stiff, highly over consolidated saturated clayey soil subject to drained shearing, pore water may generate a negative pressure and water external to the body tends to flow into the soil (or sand), and hence its total volume increases, indicative of dilation behavior. *Cf.*, contraction, soil or sand;

dioctahedral sheet In the ideal case, the smallest structural unit in a phyllosilicate contains three octahedra. If two such sites are occupied with cations and one site is vacant, then the octahedral sheet is considered “dioctahedral”. If all three sites are occupied, the sheet is considered “trioctahedral”. (*Quot* Guggenheim *et al.,* 2006; see also references therein). A dioctahedral sheet generally contains predominantly trivalent cations. *Cf.*, trioctahedral sheet

dioctahedral chlorite a species of the chlorite mineral group with dioctahedral sheets only (e.g., donbassite) *Cf.*, trioctahedral chlorite, di,trioctahedral chlorite, dioctahedral sheet

dipole moment, electrical a measure of the unequal distribution of negative (electrons) and positive (protons) charge in an atom, molecule, or solid, with units of charge times distance (1 Debye, 1 D = $3.335641*10^{-30}$ C·m = 10^{-10} esu · , where esu = electrostatic valency units). A molecule has a nonzero dipole moment if the individual bond dipole vectors do not cancel (e.g., a water molecule). *Cf.*, polarization

disilicic not a valid term, previously used as a classification of the micas where the number of silicon atoms per formula unit is two per four tetrahedral sites, see Rieder et al. (1998). *Cf.*, mica, true mica, brittle mica, interlayer-deficient mica, group names

dislocation see line defect

dispersed phase see suspension

di,trioctahedral chlorite a species of the chlorite mineral group with a dioctahedral 2:1 layer and a trioctahedral interlayer (e.g., cookeite, sudoite). *Cf.*, trioctahedral chlorite, dioctahedral chlorite, dioctahedral sheet, trioctahedral sheet

domain microfabric see microfabric, clay

double layer hydroxides see double metal hydroxides

double metal hydroxide organoclays see double metal hydroxides

double metal hydroxides a group name for naturally occurring and synthetic compounds with the general formula of $M^{2+}_{(1-x)}M^{3+}_{x}(OH)_2A^{-x}$ where M^{2+} is a divalent metal with Mg being the most common in nature (others include Ni, Cu, Ca Fe), M^{3+} is a trivalent metal normally Al or Fe (also Cr), A^- is a monovalent anion, and x is commonly near 0.3. The most common anion in nature is CO_3^{2-} [SO_4^{2-}, Cl^-, $(OH)^-$ also occur]. For divalent anions, the formula is altered to (x/2). The positively charged portion of the structure is brucite-like, with the anion portion analogous to the interlayer in the phyllosilicates. The interlayer materials are readily exchangeable and may include H_2O and occasional cations. *Syn.*, layer double hydroxides, LDH, double layer hydroxides, hydrotalcite-like group, HT, anionic clay, and various similar versions

drained shearing refers to the process of external loading of a soil (or sand) when a soil body is subject to external loading (or shearing) and the boundary condition of the soil allows drainage of porewater. If porewater flows out of the soil, the soil exhibits contractive behavior; otherwise the soil exhibits dilative behavior. See contraction, soil or sand; dilation, soil or sand

drained creep see compression, secondary; creep

drilling mud fluids (e.g., water, oils, organics) plus dissolved additives and appropriately sized, suspended solids (e.g., Na-rich bentonite, palygorskite, organoclay, barite, sand) needed to produce bulk physicochemical and rheological properties appropriate for deep bore holes and for the removal of “cuttings” generated during the drilling process. For example, one such physiochemical requirement for drilling mud is a high specific gravity to prevent blowout if high-pressure strata is encountered during drilling at depth.

driving force, crystal growth see crystal growth, driving force

drug The United States Federal Food, Drug, and Cosmetic Act (FD&C Act) of 13 March 2013 defines drugs, in part, by their intended use, as "articles intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease" and "articles (other than food) intended to affect the structure or any function of the body of man or other animals" [FD&C Act, sec. 201(g)(1)]. Clays and clay minerals are used in pharmaceuticals to enhance bioavailability, either as an excipient or an active principle, or as a way to control the release of the drug (Rodrigues et al, 2013).

earthenware a nonvitreous, porous, opaque ceramic whiteware made from milled clay, quartz, and feldspar, fired to between 950 - 1100°C. Water adsorption is variously defined as greater than 3% or greater than 5%. The material may be glazed to achieve water tightness. Earthenware is commonly used for flower pots, vases, or tile art. *Cf.*, ceramic, glaze, tile

earthy having a dull luster, similar to soil, usually involving an aggregate of fine-grained material

edge site An edge site is a binding site located on a non-basal (edge) surface of a clay mineral. *Cf.*, binding site

edge dislocation see line defect

effective stress, soil In classic soil mechanics, effective stress of a saturated clay body is the difference between the total stress and the pore water pressure. However, at the microscopic scale, effective stress must consider the actual stress involving forces transferred through particle contacts. In the stress range of interest to soil engineers, both water and soil particles are assumed incompressible, and hence the soil properties and mechanical behavior are controlled by forces involving inter-particle contacts only.

efflorescence In geology, the weathering process where salt laden ground water is brought to the surface of a geologic material by evaporation, allowing the dissolved salts (e.g., halite, gypsum, calcite, natron) to crystallize forming a white/grey, often fluffy powder. Efflorescence is common in arid climates where rocks or soils of marine origin are exposed at or near the surface.

elastic a descriptive term for tenacity where an applied force deforms a crystal, but the crystal resumes its original shape after the applied force is released. *Cf.*, flexible, brittle

elastic constants general sets of properties that describe a response of a material to elastic stress. Elastic properties are described by the modulus of elasticity (Young's modulus), bulk modulus (modulus of incompressibility), and the modulus of rigidity (μ). In the elastic regime, the induced strain is linearly proportional to the stress. *Cf.*, bulk modulus, Young's modulus.

electric dipole For atoms or molecules, an electric dipole occurs where there is a separation of positive and negative charge over a short distance. For example, an electric dipole occurs for

H_2O where (the bent) molecule forms a small negative charge near the oxygen atom whereas an equal, but positive charge forms on the opposite side of the molecule associated with the hydrogen atoms.

electrical double layer see diffuse double layer

electrical potential (ψ) the potential energy per unit of charge; the difference in electrical potential between two points is the voltage (V).

electrode An electrode is a charged wire or plate. An anode is a positively charged electrode and a cathode is a negatively charged electrode. Charged particles are attracted to the electrode of opposite charge.

electron tunneling Electron tunneling is a quantum mechanical property that occurs because electrons behave as waves of energy and are thus capable of passing through an energy barrier that would not be possible in classical mechanics. In scanning tunneling microscopy (STM), the tip and sample wave functions overlap so that when a bias voltage is applied, there is some finite probability of finding the electron on the other side of the energy barrier. Depending upon the direction of the bias voltage in STM, an electron may jump the gap or 'tunnel' across the barrier from tip to sample or from sample to tip.

electronegativity Electronegativity (electron affinity) is the ability for an atom to attract electrons. The original definition was specific to atoms, but it is often applied to functional groups, although reference to the dipole moment, polarity, and/or Lewis acid/base character may be more appropriate to describe the attraction of electrons within a particular molecule or bonding environment.

electroneutrality a constraint imposed on classical calculations or simulations of atomic structures in which the model system contains no net electric charge.

elephantiasis, nonfilarial see podoconiosis

elutriation see air classification

eluvium see deposits, eluvial

embryo In crystal nucleation theory, an incipient and metastable particle with a size smaller than a critical radius. See critical radius

emulsion see suspension

enantiomorph or **enantiomorphic pair** see mirror plane

enaulic c/f-related distribution see c/f-related distribution

end member a mineral with a formula that is stoichiometric with respect to the asymmetric unit of the cell, and therefore reflects a lack of solid solution**.** See solid solution for an example, also see asymmetric unit

endothermic see enthalpy

enthalpy Enthalpy, H, is a thermodynamic state function equal to internal energy plus the product of pressure times volume or $H = E + PV$, i.e., the heat content of the system. For example, the change in enthalpy, ΔH, is the heat involved, either released (exothermic) or absorbed (endothermic), in a system for a constant pressure process (e.g., a reaction at a fixed pressure). Exothermic reactions have a negative enthalpy change, whereas endothermic reactions have a positive enthalpy change. See state function, entropy

entropy a thermodynamic state function, which is classically defined as a change, ΔS, in a system involving reversible heat (q_{rev}) in a process and absolute temperature (T), such that $\Delta S_{\mathrm{sys}} = q_{\mathrm{rev}}/T$. A reversible heat process implies an equilibrium process, and thus the change in entropy allows the determination of the favored direction of a process or reaction. If the total entropy change is positive from the initial state to the final state, the process spontaneously occurs. Where an increase in entropy, ΔS, is positive, this indicates a greater degree of motion or randomness of atoms, molecules, or ions in a system. See enthalpy, Gibbs energy, state function

enzyme a (bio)molecule that serves as a catalyst for a chemical reaction.

epitaxy an oriented crystalline overgrowth forming on a monocrystalline substrate. This overgrowth occurs when the lattice dimensions within the common plane of the overgrowth and the substrate are similar. For moderate differences, dimensional variations of the two phases may still result in a continuous contact. However, for larger differences in the lattices of the two phases, small particles may form of the overgrowth phase if only limited accommodation occurs.

epizone the beginning of low-grade metamorphism. The epizone is defined by Kübler indices less than 0.25 in mudrock lithologies. *Cf.*, Kübler index

equipoint or **equivalent point** symmetry equivalent points, which commonly refers to positions of symmetrically equivalent atoms in a crystal structure

equivalent spherical diameter Clay particles are often size-separated using Stokes' law, although Stokes' law applies strictly to spherical particles only. Clay particles with platy shapes settle at slower rates than spheres of equal density in a fluid, however. If Stokes' law is used in the size-separation analysis, it is appropriate to describe the platy clay particle as settling at velocity equal to that of a sphere of "equivalent" diameter (equivalent spherical diameter or esd or e.s.d.). See Stokes' Law

equivalent point see equipoint

erosion movement and removal of natural materials by the action of erosive agents, such as water, ice, and wind. See weathering

esd or **e.s.d.** see equivalent spherical diameter; in statistics, this abbreviation is also used for estimated standard deviation.

essential element (medical/biological) a term broadly defined as a major element (e.g., H, O, C, N, Na, K, Ca, Mg, P, S, Cl) that plays physiologically important functions in human health. Essential elements can be derived through diet or through percutaneous migration from peloids. *Cf.*, essential trace element; see peloid

essential trace element (medical/biological) a term for trace elements (e.g., Li, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, W, Mo, Si, Se, F, I, As, Br, Sn) required for human health and specific to the function of certain proteins and enzymes. An essential trace element may be derived through percutaneous migration or through diet. *Cf.*, trace element

euhedral see crystal

eutectic the lowest (minimum temperature) point of a liquid field in a phase diagram. Cf., phase diagram

Ewald sum The Ewald sum is an approximate method used to calculate the long-range portion of a potential energy term (e.g., electrostatic) in classical simulations where periodic boundary conditions are used. Energy terms at distances less than a defined cutoff value are calculated directly in real space. However, for distances greater than this cutoff (extending to infinite distance), the energy terms are calculated in reciprocal space.

excipient The inactive ingredient in a pharmaceutical product. The excipient, often clay, may be the vehicle for the active principle or may be added to improve the physical appearance, taste, smell, or smoothness of a drug or to promote disintegration (time release) of capsules or pills. *Cf.*, active principle

exfoliation a) In clay science, exfoliation involves a degree of separation of the layers of a host structure where units, either individual layers or stacking of several layers, are isotropically dispersed (freely oriented and independent) in a solvent or polymer matrix (Bergaya et al., 2011). This may be achieved by intercalation, by mechanical means, or by other methods. Where delamination or exfoliation cannot be distinguished, use “intercalation” or “delamination/exfoliation” to describe the process. See intercalation, delamination, 1:1 layer, 2:1 layer. (From AIPEA Nomenclature Committee, 2011, unpublished) b) a process of physical weathering where large granitic plutons break into onion-like sheets along joints that lie parallel to the exposed surface.

exothermic see enthalpy

expandable clay see swelling clay

extensive property a thermodynamic property that depends upon the amount (e.g., number of moles) of a substance, for example, internal energy, *E*. *Cf.*, intensive property

extra-framework see zeolite

extrusion the process of pushing a plastic material through a die to change its shape. Commonly used in the clay industry to manufacture bricks.

***F* center defect** see point defect

Fahrenheit A temperature scale where the freezing point of pure water at one standard atmosphere is set to 32 ° and the boiling point is set to 212 °. *Cf.*, Celsius, Kelvin

failure envelope To determine how an applied stress can cause failure of a material, such as a soil mass, a failure envelope is drawn by determining a line of best fit tangent for several Mohr circles at failure. Thus, the failure envelope is the locus of all shear and normal stress points at failure for a given material. Soil strength depends upon the effective stress, and the size of the stress circles at failure varies with the stress level. By varying the stress level (e.g., the minor principle stress), the failure stress circle changes location and size, and the line that envelopes all these failure stress circles is the failure envelope. Usually it can be defined base on either effective stress or total stress, and hence it can be an effective stress envelope or a total stress envelope. The most widely used linear (Mohr-Coulomb) failure envelope is defined as tau = *c* + sigma[tan (phi)], where phi is the friction angle or the slope of the failure envelope, and *c* is the cohesion (soil strength) or the intercept of the failure envelope at the vertical axis (or the shear stress axis). *Syn.*, Mohr failure envelope, See also Mohr's circle

failure loss of cohesiveness

Faraday constant the magnitude of electric charge per mole of electrons; has the value of *F* = 96,485 coulombs/mole

fat clay a qualitative industrial term used to distinguish clays possessing high plasticity (i.e., "fat") or only slight plasticity (i.e., "lean"). The term originates from a soil classification system (Unified Soil Classification System used in both engineering and geology).

felsic a geologic term describing magmas, igneous rocks and silicate minerals that have a relatively high concentration of lighter elements such as oxygen, sodium, aluminum, silicon and potassium. Felsic magmas typically are highly viscous when compared to mafic magmas. Felsic rocks are typically light colored when compared to mafic rocks *Cf.,* mafic

ferran see cutan

ferrimagnetism a property of material where there is an antiparallel alignment of magnetic moments but these alignments are unbalanced either because one direction has stronger moments or a larger number of moments. Inverse spinel structures (“ferrites”) are often ferrimagnetic, where magnetic moments of ferric iron cations in the tetrahedral sites and one-half the cations in the octahedral sites (also ferric iron) are opposed and cancel, whereas the remaining occupied octahedral sites can have either balanced (e.g., Mg, Cd, Zn, zero unpaired electrons) or unbalanced (e.g., Mn, Fe^{2+}, Co, Ni, Cu) magnetic moments, approximately proportional to the number of unpaired electrons.

ferrites, see ferrimagnetic

ferroelectric describes a property of materials whereby an electric dipole moment remains even after a strong electric field is removed. The electric dipole moment (polarity) results from electronic polarization of individual atoms or ions, and/or a reorientation of polarizable molecules in the crystal. Dipole moments in ionic crystals can also form from initial cation positional disorder within a site from unit cell to unit cell; domains (and a dipole) develop when an applied electric field causes a favored positioning of cations within the site cavities. Examples of ferroelectric materials include KDP (potassium dihydrogen phosphate), colemanite, and barium titanate. Dipoles are randomized at the “Curie temperature”.

ferromagnetism describes a property of material where permanent magnetism develops when a magnetic field is applied. Ferromagnetism results by a parallel alignment of magnetic moments which remains after the material is removed from the applied magnetic field. The phenomenon occurs with iron, and hence the name, but other elements (in general, elements between atomic numbers of 23 and 29) and alloys (e.g., MnBi) also show the effect. Upon heating, the effect is diminished, and when heated to the “Curie temperature”, the magnetic effects are fully removed.

fibrosis see pneumoconiosis

fibrous a crystal habit describing thin, flexible filaments

fill In geotechnical engineering, fill is geological material in containment formed by human activities, such as dumping, compaction, and hydraulic deposition (via pumping).

filler A filler is a solid fine- to very fine-grained, natural or synthetic, organic or inorganic substance that bonds to the active ingredients, e.g. clay minerals, with the following properties: 1. negligible dissolution in the active material and 2. capable of being added to the excipient to reduce the amount of the active ingredients (= cost savings) without a significant reduction in the properties of the active material or to improve its properties. For example, talc and kaolinite are used as fillers in paper, cosmetics, pigments, or varnishes, and smectite is often used as a filler in plastics.

fire clay a kaolinitic-rich clay with excellent refractory properties, and the fired product is commonly used as fire bricks. The refractory clays are classed as low, medium, high, and super duty with the latter heat resistant from 1430 to 1804 °C. Fire clays are low in alkali, alkali earth, and transition metals. Typically found in association with coal layers. See refractory material. *Cf.*, underclay, seat rock

firing heat treatment of clay materials that cause partial melting and fusion to create ceramics *Cf.*, thermal activation

fissile the property of breaking or cleaving into flake-shaped, nearly planar paper-thin fragments. Fissility reflects fabric and texture such as the parallel alignment of clay minerals and phyllosilicates and fine-grain size laminations. See lamination.

fissility see fissile

flame retardancy Flame retardancy is the property of an additive that lowers the flammability of a material. Flame retardancy is measured by several standard testing methods, with the most common test being the UL94 test. However, more information is obtained by utilizing a cone calorimeter. Clay/polymer nanocomposites lower the flammability of the polymer significantly in both types of flammability tests. Clay layer-by-layer composites have been shown to greatly lower the flammability of textiles. The flammability of materials for construction and clothing is of particular interest for the interiors of airplanes, commercial and residential construction, home furnishings, children sleepware, and clothing for industrial workers. *Cf.*, layer-by-layer composites

flash heating see superheating

flexible a descriptive term for tenacity where a mineral may bend without breaking, but does not return to its original shape after the force is released. *Cf.*, elastic

flint clay a fine-particle size, non-plastic, dense, brittle kaolinitic clay layer or deposit, that breaks with a conchoidal fracture. Typically found in association with coal layers. *Cf.* underclay, seat rock

flocculation In the original, flocculation refers to the destabilization of a suspension by the clumping of small particles to larger ones, but without fusion, owing to small amounts of polymers (e.g., see Lyklema, 1991). Common usage is no longer restricted to polymers, and may involve changes of the electrolyte. However, the mechanisms of destabilization differ where polymers vs electrolytes are considered: polymers are adsorbed and form bridges between particles, whereas electrolyte changes involve ionic strength variations that reduce repulsive forces between particles. Both processes produce clumping of small particles in a suspension to produce larger particles. The total surface area does not essentially change. *Syn.*, aggregation

floccule A cluster of loosely bound particles in a suspension that combine to produce a larger particle. In clay mineralogy, a floccule, or “floc”, is comprised of very fine-grained clay minerals in association with fine silt and organic debris, held together by electrostatic forces or organic sheaths (after Potter et al., 2005). See flocculation.

flow quick-clay landslide see quick-clay landslide

flux a) In metallurgy, a material which chemically cleans a metal surface to prepare it for welding, brazing or soldering. b) In ceramics, a material which lowers the meting point of ceramic materials to facilitate glass formation. c) In physics, the rate of transfer of heat, mass, magnetism, etc. that passes a unit area per unit time. *Cf.*, fusion

fluxing melting of a substance

fluxional bond a dynamic bond where atoms exchange between symmetry-related sites. In cases where the configurations are non-equivalent, the result is an isomer or tautomer, whereas a fluxional molecule involves chemically equivalent configurations.

fly ash fine particulate, airborne, typically amorphous, siliceous residue from burning coal in industrial burners. The chemistry of the coal and the type/chemistry of the fly ash collection system determines the composition of the fly ash. Pozzolanic (cementitious) fly ash is commonly used as an additive in cement. Non-pozzolanic fly ash is often used as a filler in wood and plastic products, in asphaltic concrete, in roofing tiles, and in other composite manufactured materials. Fly ash commonly contains a variety of heavy metals that were present in trace concentration in the unburned coal. *Cf.,* bottom ash

foam see suspension

fog see suspension

force field A force field is derived from a set of parameters determined from an approximate energy expression and then used to calculate interatomic or intermolecular energies in a classical calculation or simulation of an atomic structure. Most force field methods include pairwise interatomic interactions (*e.g*., van der Waals, electrostatic), and some include intramolecular interactions (*e.g*., bond stretch, angle bend) present in polyatomic species. Interaction parameters are adjusted so that results obtained from the force field, such as structural, mechanical, and spectroscopic properties, match those from experiment or quantum mechanical calculations as closely as possible.

form a) in mineralogy, a crystal shape that is an expression of the ordered pattern of the atomic structure. The crystal form is commonly a regular geometric shape. b) in crystallography, a form consists of a group of symmetry-related crystal faces.

formality the number of gram formula weights (= molecular weights) of the solute in one liter of solution. Useful where experiments use measured volumes and where temperature effects are not being studied. *Cf.*, molarity, normality, molality, mole fraction

free-swell test A free-swell test is a process- or quality-control test to measure the compatibility of a clay with various solvents by placing a specified amount of clay in the fluid of interest, allowing it to remain undisturbed, and by determining the amount of swelling after a specified time. A graduated cylinder is often used to judge the amount of swelling after one or two hours, and 1 gram of clay is typically used, although each manufacturer/supplier follows their own protocols. The test is relative to a clay with no swelling behavior, as there are no standard-swelling behaviors. The test is especially useful to determine the optimum organoclay for paint or grease formulations.

freeze drying a dehydration process where material is dried via sublimation of contained water. The material is frozen in a vessel, subjected to gas-pressure reduction often followed by slight heating, and dried by removal of sublimated water vapor. In clay mineralogy, samples of clay are dispersed in water as a suspension prior to freeze drying. The residual clay often shows the aggregate structure and fabric of the dispersed phase.

Frenkel defect see point defect

friable the characteristic of a solid material that allows its particle size to be easily reduced

fugacity see activity

full width at half maximum (FWHM) In X-ray diffraction studies, full width at half maximum (FWHM) is a mathematical expression that describes the width (the independent variable, or the difference in two-theta values and thus "broadness") of a reflection with a local maximum value (dependent variable, or the X-ray intensity and thus the "peak"). The FWHM value is calculated by subtracting the lower two-theta value from the higher two-theta value, which are at the position of half the maximum intensity value (a local reflection maximum). The FWHM value is often used in clay science to describe the reflection width in X-ray diffraction patterns for clay minerals. Other techniques, such as spectroscopic methods also use this expression, although with other independent and dependent variables (e.g., X-ray photon energy). The advantage of the FWHM expression (vs using the local maximum as the reflection location) is that reflection maxima are not always representative of the true reflection position, and the FWHM eliminates (or minimizes) the determination of errors in reflection position. *Cf.*, X-ray diffraction

fuller's earth a clay or other earthy material of fine particle size that is highly absorbent and/or is a natural bleaching earth. The term is derived from the historical use of certain clays to "full" or remove oils and other contaminants from raw woolen cloth.

fulvic acid Fulvic acids occur as a result of the decay of plants and microorganisms in some soils, sediments, peats, coals, shales, and surface waters. Unlike humic acids, fulvic acids are soluble in water over a large range of pH values (and this is the operational distinction between humic vs fulvic acids). Along with humic acid, fulvic acid may be extracted from solids using a strong base, such as NaOH or KOH. Fulvic acid may actually originate from hydrolysis of large molecules by the strong base during extraction. However, at pH 1, fulvic acid remains in solution but humic acid will precipitate. *Cf.*, humic acid, humification, humic substances, humin

fundamental particle a sequence of 2:1 dioctahedral or trioctahedral layers which are coherently related by rotations of multiples of 60°. Such particles, as observed in sample separates, are assumed to be identical to the individual growth units in unseparated samples. Some data have shown that coherent scattering domains undergo separation during sample disaggregation, and that particles that result are not fundamental, but many investigators assume that there is a one-to-one relation between fundamental particles in separates and coherent scattering domains in unseparated soil or rock samples. *Cf.*, MacEwan crystallite, interparticle diffraction, coherent scattering domain

fusion the unification of two or more particles such that the substances between the two particles is of the same material as the particles. Fusion often refers to the melting together of two substances. In clay science, aggregates may form without fusion with bridges forming between particles by H_2O or by polymers, such that they behave as an apparently larger particle. *Cf.*, flocculation

gallery see pillared clay

gangue In mining, the non-economic host rock in which valuable minerals (usually metalliferous ore minerals) are found. When the gangue is discarded, this material is referred to as "tailings".

gastrolith a small mineral concretion in the stomach. Some gastroliths may form if excess (ingested) clay cannot be eliminated by the digestive system. Some species, such as birds, reptiles, or dinosaurs, swallow small stones (gastroliths) that are believed to aid in digestion. These gastroliths are generally not concretions and are rounded and polished owing to the abrasive action within the stomach.

GCMC see Grand Canonical Monte Carlo

gefuric c/f-related distribution see c/f-related distribution

gel see suspension

gel strength A measure of the ability of a colloidal system (i.e., a gel or sol) to withstand a load (shear force) without loss of the high slurry viscosity and/or the mechanical elasticity, often measured with a rheometer and expressed in units of mass per area. The gel strength is a function of the inter-particle forces present in the solid-liquid system. *Cf.*, colloid, suspension, gel, sol

gelling clay an industrial term for clay minerals (especially palygorskite, sepiolite, Na- or Na-exchanged montmorillonite, hectorite, and organoclay) having a high slurry viscosity at low percent solids when mixed with fluid. Such clay minerals form a colloid where the dispersed phase and the dispersion medium produce a semisolid material, similar to jelly. Industrial applications include thickening/suspension agents, adhesives, sealants, putties and glazing compounds. Jelling viscosity is typically measured on Fann or Brookfield viscometers. For aqueous applications and some fibrous clay minerals such as palygorskite, the gelling behavior and viscosity is enhanced by adding magnesium oxide or by extruding the slurry to align the needle-shaped crystallites. For montmorillonite, gelling behavior can be enhanced by soda ash treatments to increase the exchangeable Na-cation content and the swelling capacity of the clay mineral. For solvent-based applications, various smectites can be surface modified by quaternary-amine compounds to form organoclays that display superb gelling characteristics. See colloid

geophagy the deliberate ingestion of (specifically) soil/clay; a form of pica. *Cf.*, pica

geopolymer Geopolymers are inorganic binders used as cement substitutes. Geopolymers are made from activated (commonly heated or milled) silicate or aluminosilicate materials and are composed of poorly crystalline Al, Si networks. Commonly, thermally activated clay, i.e., metaclay (often metakaolin) is used, but geopolymers can be produced from feldspar, impure clay-rich interstratifications, waste product from coal combustion or metallic ores, fly ash or other ash material, iron oxides, or ground blast-furnace slag. These starting materials are mixed with an alkali or alkaline earth metal hydroxide solution such as KOH, NaOH or $Ca(HO)_2$ (= alkali activation). The alkali or alkaline earth metal hydroxide solution dissolves Al, Si and alkali or alkaline earth elements. During the hardening process, the dissolved species polymerize to form a network characterized by short-range ordering. The name geopolymer is derived from "geo", which refers to the origin of the precursor, and "polymer", which refers to the linking of molecules in a repeated fashion. *Cf.*, alkali activation, blast-furnace slag, geopolymerization, glass, metaclay, metakaolin, thermal activation

geopolymerization the process of forming geopolymer cements. The gel-like mixture of the activated starting material (often metaclay) and the alkaline solution hardens upon drying by evaporation of water, forming a three dimensional inorganic network (geopolymer) by polymerization of Al and Si. *Cf.*, geopolymer, hardening, metaclay

geotherapy commercialized therapies using geologic materials, such as peloids, or processes, e.g., hot springs or mud baths. *Cf.*, peloid, pelotherapy

Gibbs energy a thermodynamic state property useful to determine the spontaneity of a reaction within a system (without regard to the surroundings as is the case with entropy changes) and the direction of the reaction. The change in Gibbs energy, ΔG, is equal to $\Delta H - T\Delta S$, where ΔH is the change in enthalpy (cal/mole), T is the absolute temperature (K), and ΔS is the change in entropy (cal deg^{-1} $mole^{-1}$). A substance reacts if the change in Gibbs energy is negative going from the initial state to the final state. Gibbs energy is often referred to as Gibbs free energy. See enthalpy, entropy, state function

Gibbs free energy See Gibbs energy

glaebule a pedofeature forming segregated lumps of material with diverse composition (similar to cutans) as part of a soil groundmass. The non-planar shapes and more distinct outlines differentiate glaebules from cutans. Three common glaebules include mottles, nodules, and concretions.

nodule a glaebule that is irregular to nearly spherical, with a massive internal structure.
concretion a nodule-shaped glaebule showing an internal structure of concentric layers.

mottle poorly differentiated glaebules occurring as diffuse patches in the groundmass.

glass a solid with a degree of order intermediate to the highly ordered arrangement of atoms, molecules, or ions in a "crystalline" solid and the highly disordered arrangement as found in a "gas". Most glasses are in a metastable state and can be described as a supercooled liquid, which lack a melting point. Rapid cooling from a molten state (e.g., magma, lava) may result in a glass and this commonly depends on the volatile content of the melt. Not all glasses are formed from a melt. Although most opal forms from silica-saturated fluid under near-surface conditions, a rare "non-crystalline opal" (e.g., opal-AN) forms by transport of silica via steam to cold surfaces.

glaze A glaze is a vitreous, watertight coating often used to seal porous ceramics, such as earthenware. Glazes are commonly made from clay mixed with a flux to lower the melting temperature, then applied to the green body and fired. Colorants, commonly iron, copper, or cobalt compounds, may be added, especially to color vases or tiles. *Cf.*, ceramic, earthenware, green body, tile

glide plane symmetry involving reflection across a plane coupled with a translation of $a/2$, $b/2$ or $c/2$ parallel to an axis (a-glide, b-glide, or c-glide, respectively) or between two axes (n-glide with translations of $a/2 + b/2$, $b/2 + c/2$, or $a/2 + c/2$; d-glide or diamond glide with translations of $a/4 + b/4$, $b/4 + c/4$, or $a/4 + c/4$) or between three axes for tetragonal or isometric crystals with a translation component of $a/4 + b/4 + c/4$.

Grand Canonical Monte Carlo simulation (GCMC) a Monte Carlo molecular simulation that is based on the grand canonical thermodynamic ensemble, an ensemble (e.g., a system of particles) in statistical mechanics that describes the possible states of the particles in equilibrium. The model system properties of chemical potential, volume, and temperature are held constant, but the number of particles in the system (*e.g.*, interlayer water molecules) is allowed to vary as equilibrium is achieved. In this context, equilibrium implies both potential energy and system density (number of particles). Monte Carlo moves are accepted based on the energy change of the move according to a Boltzmann probability (so that some moves resulting in higher energy are accepted). *Cf.*, force field, molecular dynamics, Monte Carlo molecular simulation

granostriated b-fabric see b-fabric

green strength a) In clayware manufacture, the ability of an unfired, molded clay body to resist mechanical deformation. b) In metal casting, a measure of the ability of a bentonite-bound sand mold to resist deformation (also called "green sand strength").

green sand strength see green strength

green body A green body is an unfired clay-based object, e.g., made from mixtures of milled clay, quartz, feldspar, and appropriate amounts of water, and formed by molding, pressing, or by a potter's wheel. The green body is fired in kilns to obtain a ceramic object. *Syn.*, greenware; *Cf.*, ceramic, pottery

greenware see green body

grit a qualitative term in the clay-mining industry that refers to small, hard accessory minerals occurring in the bulk clay deposit, such as quartz, feldspar, rutile, ilmenite, and apatite, which imparts an undesirable "abrasive" character to the bulk clay.

groundwater water existing underground in voids or pore spaces in rock or sediment

group names Phyllosilicates are classified on the basis of characteristics involving planar structures, non-planar structures and regular interstratifications (e.g., Guggenheim et al., 2006). For planar structures and regular interstratifications, the layer type (e.g., 1:1, 2:1) is further divided by interlayer material present that is required to offset the net negative charge on the layer, and each division is given a group name. In addition, each group has a generally characteristic spacing [based on the $d(001)$] perpendicular to the stacking direction, i.e., $c\sin\beta$. The group names ($x \sim$ layer charge per formula unit) for the planar structures (interstratifications are not given here) are: serpentine-kaolin ($x \sim 0$, $c\sin\beta \sim 7.1\text{-}7.3$ Å), talc-pyrophyllite ($x \sim 0$, $c\sin\beta \sim 9.1\text{-}9.4$ Å), smectite ($x \sim -0.2$ to -0.6, $c\sin\beta \sim 14.4\text{-}15.6$ Å), vermiculite ($x \sim -0.6$ to -0.9, $c\sin\beta \sim 14.4\text{-}15.6$ Å), true mica ($x \sim -1.0$, $c\sin\beta \sim 9.6\text{-}10.1$ Å), brittle mica ($x \sim -2.0$, $c\sin\beta \sim 9.6\text{-}10.1$ Å), interlayer-deficient mica ($x \sim -0.6$ to -0.85, $c\sin\beta \sim 9.6\text{-}10.1$ Å), and chlorite ($x \sim$ variable, $c\sin\beta \sim 14.0\text{-}14.4$ Å). Groups are further divided into subgroups (e.g., serpentine, kaolin, talc, pyrophyllite, trioctahedral smectite, dioctahedral smectite, etc.) by mineral species based on the octahedral character (i.e., dioctahedral, trioctahedral) and subgroups are divided based on chemical composition to mineral species. Bailey (1980) designated the trioctahedral smectite subgroup as saponite and the dioctahedral smectite subgroup as montmorillonite.

H_2O^- see water, adsorbed

H_2O^+ see water, structural

habit Habit refers to the general shape of mineral particles, as in the "platy" habit of clay particles, inclusive of shapes that reflect the internal arrangement of atoms as well as crystal growth features. Examples of habits include acicular, lamellar, and equant.

Hamaker constant The Hamaker constant, A, describes the attractive force between two solid surfaces due to temporary dipole forces (van der Waals interactions). For ideal planar surfaces separated by length L, the van der Waals potential energy is proportional to A/L^2.

half life the time, $t_{1/2}$, required for the number of radioactive atoms in a system to decay and thus decrease to half of the original number.

hardening a process involving the formation of cements (e.g., Portland cement, geopolymers) during which intermediate phases [e.g., calcium silicate (CS) phases in Portland cement] (re)crystallize to new phases by hydration (e.g., Portland cement) or dehydration (e.g., geopolymer cement). Ingredients (e.g., naphthalene sulfonate, a plastifier) may be added to delay hardening. *Cf.*, calcium silicate (CS) phases, calcium silicate hydrate (CSH) phases, geopolymer, geopolymerization, Portland cement

hardness In mineralogy, hardness is the resistance to scratching. Mohs' scale of hardness is generally used to obtain relative hardness information by comparing (i.e., by a scratch test) an unknown to one of ten minerals defined in the Mohs' hardness scale. Hardness tests are performed on a smooth surface of the unknown. Hardness is not an isotropic property and thus, may depend on the direction in which the surface is scratched, although the differences in most minerals are small. *Cf.*, Mohs hardness, Vickers hardness

healing clay clay used therapeutically, for example, to alleviate pain, absorb toxins, reduce swelling, or protect skin. Common healing clays are montmorillonite (in bentonite), palygorskite/sepiolite, and kaolin. *Cf.*, active principle, aesthetic medicine, antibacterial clay, geotherapy, medicinal clay, pelotherapy

heat of vaporization the energy (often heat) required to transform a given quantity of a liquid into a gas or vapor without changing temperature. *Cf.*, heat of sublimation, heat of fusion

heat of fusion the energy (often heat) required to transform a given quantity of a solid to a melt without changing temperature. *Cf.*, heat of sublimation, heat of vaporization

heat of sublimation the energy (often heat) required to directly transform a given quantity of a solid to a gas without changing temperature (or going through the liquid state). The heat of sublimation is the sum of the heat of fusion and heat of vaporization at the given temperature. *Cf.*, heat of vaporization, heat of fusion

heat capacity a measure of the heat energy required to raise the temperature of a substance by 1 ºC. For example, the specific heat energy or capacity is the amount of heat needed to raise 1 gram of a substance by 1 ºC. The heat capacity is, therefore, equal to the mass of the substance times the specific heat. Thus, the molar heat capacity is the heat capacity per mole.

Helmholtz plane see *Stern layer*

hemostatic wound dressing Hemostatic wound dressings are used to control bleeding when tissue damage occurs. One active ingredient applied either directly or with gauze bandages to a wound is clay (commonly, kaolins, zeolites, and smectites), which is used to absorb fluid and to promote blood clotting.

heterogeneous reaction a reaction that involves more than one physical state (i.e., solid, liquid, gas). *Cf.*, homogeneous reaction

heterogeneous nucleation precipitation from solution of one solid phase on another.

hexadecyltrimethylammonium organoclay expandable 2:1 clays (e.g. smectite, vermiculite) treated with solutions of the quaternary alkylammonium salt, hexadecyltrimethylammonium (HDTMA) bromide (also called cetyltrimethylammonium bromide), form organophilic-type organoclay. HDTMA organoclay can effectively remove organic contaminants, such as toluene, from water; see Boyd et al. (1988). *Cf.*, adsorptive organoclays, organoclay, organophilic-type organoclay

hexagonal see crystal system

high-activity clays In geotechnical engineering, high-activity clays have activities that range from about >1 to 7+, with smectitic clays (i.e., smectite or interstratifications with a smectite-like component) being the most common having activities near 3 (where Ca-saturated, or in high salinity environments) to 7+ (where Na-dominated and at low salinity). See activity, clay; low-activity clays; quick clays

Hinckley index Hinckley (1963) attempted to define the "crystallinity" of kaolinite by describing changes in the powder X-ray diffraction pattern for various samples of kaolinite. The procedure, however, does not quantify the diversity of defects present and, if the procedure is used, it should not be characterized as a "crystallinity" index. See also, Plancon and Zacharie (1990); Guggenheim *et al.* (2002). *Cf.*, crystalline, crystallinity index, Kübler index, Arkai index

homogeneous reaction a reaction that involves only one physical state (i.e., solid, liquid, gas). *Cf.*, heterogeneous reaction

homogeneous nucleation direct precipitation of a solid phase within a solution and not on the surface of another phase.

honeycomb microfabric see microfabric, clay

hormite a mining term, now obsolete and not used in the geologic literature, that refers to the palygorskite-sepiolite group (Brindley and Pedro, 1970; Bailey *et al.*, 1971a).

HT see double metal hydroxides

humic substances the general term that includes (large-molecule) humic acid, fulvic acid, and humin, all of which form the natural organic matter (NOM) of some soils, sediments, peats, coals, and shales. Non-humic materials, such as amino acids, peptides, and sugars, may also be present in some soils as NOM. Humic substances impart the brown or black color to some soils and surface waters as well as biological productivity. Humic substances do not further biodegrade readily. Humic substances are quite heterogeneous and complex, and studies often provide average properties and chemical compositions. However, Lehmann and Kleber (2015) have suggested that large-molecule humic substances do not actually exist in soils, and NOM form from a progressive breakdown of organic compounds. *cf.*, fulvic acid, humic acid, humification, humin

humic acid Humic acids are chemically diverse acids that result from the decay of plants and microorganisms in some soils, sediments, peats, coals, shales, and surface waters. These acids are insoluble in water at low pH, can be precipitated at a pH = 1, and extracted from solids using a strong base, such as NaOH or KOH. *cf.*, fulvic acid, humic substances, humification, humin

humidity amount of water vapor contained in the atmosphere. “Relative humidity” is the ratio, usually expressed as a percent, of the amount of water vapor in the atmosphere to the maximum water vapor in the atmosphere possible at a specific temperature. “Absolute humidity” is the mass of water vapor per unit of dry air. When unspecified, reference is usually being made to relative humidity.

humification a process involving the decay of plant and microorganism matter to produce the natural organic matter (NOM) as found in some soils, sediments, peats, coals, and shales. Plant lignin, related transformation phases, polysaccharides, melanin, cutin, proteins, lipids, nucleic acids, and fine char particles, are materials involved in humification. *cf.*, fulvic acid, humic acid, humic substances, humin

humin Humin occurs as a result of the decay of plants and microorganisms in some soils, sediments, peats, coals, and shales, but not aquatic waters (humin is not soluble in water). Humin may be formed also in the dehydration of some sugars. Humin, along with fulvic acid and humic acid, is a humic substance. However, humin cannot be extracted from humic substances with either a strong base or a strong acid, whereas fulvic or humic acids can be extracted. *cf.*, fulvic acid, humic acid, humic substances, humification

hydraulic conductivity In geotechnical engineering, hydraulic conductivity refers to the ease of fluid flow (for example, permeability) through sediment, rock or soil, and is affected by the viscosity of the fluid (water). *Cf.*, permeability

hydraulic head The hydraulic head is the total energy of moving water (including porewater or groundwater), usually represented by the height of water column with a unit of length. The total hydraulic head is the summation of the velocity head (kinetic energy), pressure head (potential energy), and elevation head (potential energy), all converted to the height of the equivalent water column: $\mathrm{h} = h_v + h_p + h_E = v^2/2g + u/\gamma_w + z$, where h is the total hydraulic head, and subscripts V, P, and E denote velocity, pressure, and elevation; v is the velocity; g gravity, u water/fluid pressure, γ_w unit weight of water at 25 °C, and z elevation.

hydraulic gradient In an aquifer, the ratio of total hydraulic head loss (or difference) to the length of flow path in a given direction, or in a simple description, the slope of the surface of the water table.

hydrogen bond The hydrogen (H) atom in solids is often asymmetrically located between an electronegative donor atom (D) and an electronegative acceptor (A) atom, such that the D-H distance is smaller than the H-A distance. The H atom can penetrate the electron cloud of the donor atom. The D-H--A configuration may be linear or bent, and there may be multiple A atoms. The overall bond is considered essentially ionic in character, with an overall bond strength (for D-H--A configurations) considerably weaker than a (sigma) covalent bond but considerably stronger than van der Waals interactions. The H atom may serve to balance overall charge, for example as an O-H in oxygen-based structures, in which case the H does not link a donor to an acceptor atom.

hydrolysis a) occurs when a molecule reacts with water to break a chemical bond, and thereby often incorporating H_2O into the substance. b) Hydrolysis at a surface involves the breakdown of the H_2O molecule into hydroxides and protons to form protonated/deprotonated surface sites.

hydrometer a device used to measure the specific gravity of a fluid, usually containing suspended particles. In soil analysis, a hydrometer is used to measure the particle size distribution of fine-grained (< 75 µm) soils such as clays, on the basis of the Stokes' Law: the settling velocity of suspended particles depends upon the particle size. With a time sequence of measurements of the suspension density, the quantity of particles settling out of the suspension can be estimated, and hence the size – quantity relationship (or particle size distribution) of different particles can be obtained.

hydrophilic surfaces or molecules with strong attraction for H_2O. Hydrophilic solutes are polarizable and tend to dissolve more readily in water than in oil. *Cf.*, hydrophobic

hydrophobic hydrophobic materials, either surfaces or molecules, have little or no affinity for H_2O. *Cf.*, hydrophilic

hydrotalcite-like group see double metal hydroxides

hydroxy interlayer The hydroxy interlayer is comprised of Al--OH^-,H_2O complexes (also possibly with Fe^{3+} or Mg^{2+}) and is located in the space (or interlayer) between the 2:1 layers of phyllosilicates. The cations are octahedrally coordinated by the H_2O and OH^-. The hydroxy-interlayer does not form continuous sheets and additional H_2O may occur above and below the Al--OH^-, H_2O complexes. See hydroxy-interlayered mineral. *Cf.*, hydroxy interlayering, hydroxy-interlayered smectite, hydroxy-interlayered vermiculite

hydroxy interlayering Hydroxy interlayering is a process that commonly occurs in upper soil horizons where 2:1 layer phyllosilicates (e.g., smectite, vermiculite, mica) are transformed to their hydroxy-interlayered equivalents by incorporation and polymerization of Al^{3+} and OH^- and/or H_2O. These Al–$(OH)^-$, H_2O complexes (also possibly with Fe^{3+} or Mg^{2+}) are located in the interlayer between the 2:1 layers, and do not form continuous sheets. In nature, the origin of the Al^{3+} is from the dissolution of silicates, such as feldspar and chlorite. See hydroxy-interlayered mineral. *Cf.*, hydroxy interlayer, hydroxy-interlayered smectite, hydroxy-interlayered vermiculite, mica, smectite, vermiculite

hydroxy-interlayered vermiculite (HIV) Hydroxy-interlayered vermiculites are 2:1 layer phyllosilicates with a permanent layer charge of 0.6 - 0.9 per formula unit and with fixed complexes in the interlayer. These complexes are composed of cations, mainly Al^{3+}, but possibly Mg^{2+} and Fe^{3+}, octahedrally coordinated by H_2O and OH^-. Presumably, the high-charge Al^{3+} fixes the complex, which thus limits swelling or shrinking capabilities. Depending on the degree of hydroxy-interlayering (proportion of exchangeable cations replaced by fixed complexes), the transition between vermiculite and hydroxy-interlayered vermiculite is poorly defined. Vermiculite and HIV phases are often interstratified. See hydroxy-interlayered mineral. *Cf.*, hydroxy interlayer, hydroxy interlayering, hydroxy-interlayered smectite, smectite, vermiculite

hydroxy-interlayered mineral (HIM) Hydroxy-interlayered minerals are 2:1 layer phyllosilicates with Al^{3+} and possibly Mg^{2+} and Fe^{3+} complexes in the interlayer. These complexes are formed by polymerization of usually Al^{3+} cations octahedrally coordinated by $(OH)^-$ and/or H_2O. Complexes are limited to one to five octahedra without forming a continuous sheet or Keggin ions (Al_{13}), although it is possible that additional H_2O may occur adjacent to the 2:1 layer. The permanent layer charge of HIMs per formula unit is believed to vary from 0.2 (equivalent to low-charge smectite) to 1.0 (equivalent to true mica). HIMs commonly form in upper soil horizons from smectite, vermiculite, or mica during the acidic weathering of soils. The fixed interlayer complexes reduce the ability of swelling and shrinking and thus soil fertility. These phases are commonly identified by X-ray diffraction and cation exchange capacity measurements. *Cf.*, chemical weathering, hydroxy-interlayer, hydroxy-interlayering, hydroxy-interlayered smectite, hydroxy-interlayered vermiculite, Keggin ion, pillared clay

hydroxy-interlayered smectite (HIS) Hydroxy-interlayered smectites are 2:1 phyllosilicates with a permanent layer charge of approx. 0.2 - 0.6 per formula unit and with fixed interlayer complexes. These complexes are composed of cations, mainly Al^{3+}, but possibly Mg^{2+} and Fe^{3+}, octahedrally coordinated by H_2O and OH^-. Presumably, the high-charge Al^{3+} fixes the complex, which thus limits swelling or shrinking capabilities. Depending on the degree of hydroxy-interlayering (proportion of exchangeable cations replaced by fixed complexes), the transition between smectite and hydroxy-interlayered smectite is poorly defined. Smectite and HIS phases are commonly interstratified. See hydroxy-interlayered mineral. *Cf.*, hydroxyl interlayer, hydroxyl interlayering, hydroxy-interlayered vermiculite, smectite, vermiculite

hypo-coating In micromorphology of soils, hypo-coating is a pedofeature that consists of a layer of material that is related and immediately adjacent to the surface of, for example, voids, grains, or aggregates. *Syn.*, neo-cutan; *Cf.*, coating, cutan, quasi-coating

identipoint an identical point (a point whose environment is exactly the same as the environment around each other point) placed on an array. A set of identipoints within an atomic structure shows the scheme of repetition, or translational periodicity, of an array. *Cf.*, array, structure, Bravais lattice

iep see point of zero charge

improper rotation axis see rotoinversion axis

impurity defect see point defect

incongruent dissolution Incongruent dissolution is where the release of constituents from the dissolving phase into the solution does not reflect the stoichiometry of the original phase. *Cf.*, congruent melting, congruent dissolution, incongruent melting

incongruent melting a reaction where the solid phase reacts to form a mixture of liquid plus crystals, with neither having the composition of the original solid. *Cf.*, congruent melting, incongruent dissolution

indurate hardening of a rock or sediments by the effects of temperature, pressure, cementation, etc.

inheritance a) the phenomenon by which minerals are formed in another environment in space or time from that where they are now found. b) The term is also used when some element of a pre-existing mineral structure is inherited by another mineral via the phenomenon of transformation. See also neoformation, transformation

inner sphere complexes Inner sphere complexes are ions, which adsorb in the inner Helmholtz plane. There is spectroscopic evidence that these ions come so close to the surface that, e.g., water molecules from a hydration shell have to be removed from the contact plane. Since adsorption of ions on an increasingly charged surface requires energy from bonding, one speaks of specific adsorption.

insulator, electrical materials that are poor conductors of electricity. *Syn.*, dielectric

intensive property a thermodynamic property that is independent of the amount of a substance, such as the property of heat capacity. *Cf.*, extensive property

intercalation Intercalation is a general term to describe the movement of atoms, ions or molecules into a layered host structure, often a swelling clay mineral. This process can be reversible or non-reversible. The host-structure layers are essentially unchanged with the inserted material going between the layers. The layers must remain semi-contiguous via stacking. Intercalation commonly involves cation exchange or solvation reactions. Intercalation may involve, for example, H_2O molecules or surfactants of single planes (monolayers) to paraffin-type layers between the layers of the host phase. The resulting structure is an “intercalated structure”. See delamination, exfoliation. (From AIPEA Nomenclature Committee, 2011, unpublished)

interference colors In optical crystallography, an interference color results with crossed polarizers where light enters an appropriately crystalline medium and refracts (separates into two ray fronts); thus, each wave front travels at slightly different velocities with a change in both speed and direction. Upon leaving the medium, the wave fronts interfere (recombine) and produces a component of light where there is a difference, or retardation, between the two wave fronts. This difference results in a change in wavelength in the final wave front, which produces a change in color, called an interference color.

interlayer A general term that implies either the region between the two adjacent layers or the relation between the two adjacent layers (*quot* Guggenheim *et al.*, 2009). “Interlayer distance” is more precise to describe the distance between the adjacent layers (tetrahedral sheet to tetrahedral sheet, as shown in Fig. 2), and is measured by taking the average of the *z* coordinate of the basal oxygen plane. The “interlayer displacement” describes the displacement portion or lateral shift from tetrahedral sheet to tetrahedral sheet across the interlayer space. *Cf.*, layer, layer displacement

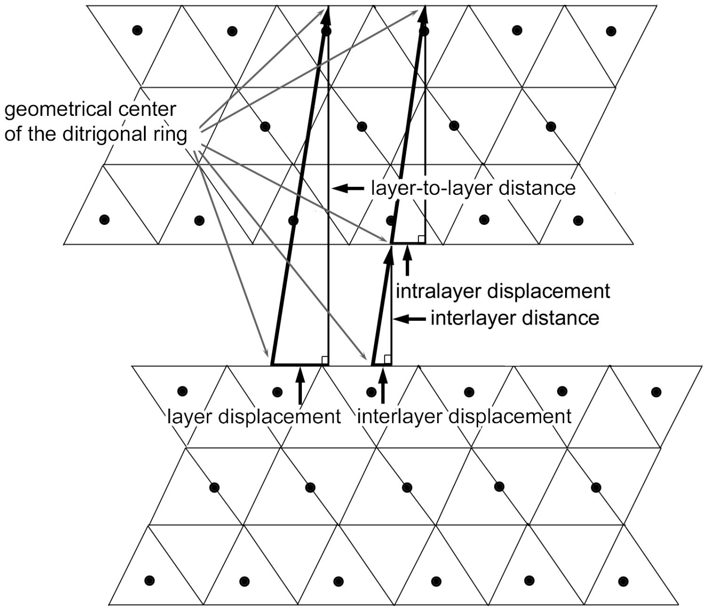

Figure 2. Illustration of terms used to describe interlayer, layers, and intralayer topologies. From Guggenheim *et al.* (2009).

interlayer material For phyllosilicates, interlayer material separates the 1:1 or 2:1 layers and generally may consist of cations, hydrated cations, organic material, hydroxide octahedra, hydroxide octahedral sheets (see fig. 2), and/or hydroxy-interlayers as a combination of H_2O and hydroxyl-coordinated cations. The interlayer material offsets the net negative charge of the layer. In certain cases (e.g., talc, pyrophyllite, where the net layer charge is zero), there is no interlayer material, and an interlayer separating the layers is empty. After Guggenheim *et al.* (2006). *Cf.*, layer; hydroxy-interlayer

interlayer shift see interlayer

interlayer distance see interlayer

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interlayer displacement see interlayer

interlayer-deficient mica abbreviated from interlayer-cation-deficient mica (Rieder et al., 1998). A group name for platy phyllosilicates of 2:1 layer and a layer charge of between -0.6 to -0.85 per formula unit. Interlayer-deficient micas do not have swelling capacity. The subgroups of the brittle micas are based on dioctahedral or trioctahedral character (wonesite is the only known member of the trioctahedral subgroup), and species within the subgroups are based on chemical composition. The value of -0.6 is a general limit, as wonesite appears to be an exception with a layer charge of -0.5, although it has no swelling capacity. The value of -0.85 has been fixed from examples of dioctahedral species only. Previous to Rieder et al. (1998), the term “hydromica” was used to express a perceived excess in H_2O above the $O_{10}(OH)_2$ formula unit, but these phases are either interstratifications (e.g., hydrobiotite = interstratification of biotite and vermiculite) or micas that exhibit a deficiency in interlayer cation occupancy. Thus, the term “hydromica” was abandoned in favor of interlayer-deficient mica. The term for species “hydrobiotite” was confusing, and the use of the prefix “hydro” is now avoided. *Cf.,* mica, true mica, brittle mica, group names

interparticle diffraction a concept introduced by Nadeau *et al*. (1984) which theorizes that individual clay mineral particles of oriented samples used in X-ray diffraction studies are stacked in aggregated composite particles which coherently scatter radiation so as to give rise to 00l diffraction patterns similar to those of uncleaved McEwan crystallites. The composite particles are theorized to be produced during sample preparation following disaggregation of original rock or soil samples.

interstratification a clay material where two or more kinds of layers are interleaved in a coherently diffracting structural domain with a degree of ordering which may vary from random to completely ordered. Layers may be 1:1 layers or 2:1 layers and interlayers may be of swelling or non-swelling nature. X-ray diffraction and transmission electron diffraction (TEM) are two common techniques used to determine layer proportions and regularity of interleaving. Energy dispersive techniques are commonly used to obtain chemical information. Regular interstratifications may be designated as mineral species, provided that they conform to specific criteria as specified by the International Mineralogical Association. Non-regular interstratifications are commonly characterized according to the information available, e.g., mica-smectite irregular interstratification, and do not warrant species status.

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intracrystalline swelling Intracrystalline swelling involves an increase in the layer-to-layer spacing of a phyllosilicate mineral to accommodate H_2O or other molecules in the interlayer. For example, in swelling clays, an increase in the relative humidity around the clay mineral particle, causes interlayer expansion, resulting in partially or fully hydrated interlayer ions. *Cf.*, osmotic swelling

intralayer displacement see layer displacement

intrinsic stability constant a stability constant, K, for a complex is determined from the activity of the complex in solution divided by the activity of the reactants in a system at equilibrium. The larger the value of K, the greater is the stability of the complex. For multiple complexes that may result in a reaction, several constants may be determined, thus K_{overall} is the product of multiple constants: K_1 x K_2 x K_3... 'Intrinsic' is used because the stability constant is an essential physical chemical parameter that relates concentrations of the components of a reaction at equilibrium.

intumescence an irreversible expansion of a solid upon rapid heating. Interstratified mica-vermiculite commonly shows expansion upon rapid heating owing to the loss of interlayer H_2O at relatively low temperatures. The separation of the locally collapsed layers (interstratified mica) increases the pressure locally, inhibits H_2O outgassing, leading to expansion, which produces worm-looking threads (Hillier et al., 2013). According to Grim (1968), Web (1824) first used the term vermiculite (the sample was probably impure with interstratified mica-vermiculite) because samples produced the wormy threads, and it is this characteristic that gives the vermiculite group its name: *vermiculari*, to breed worms, in Latin. As expected, Hillier et al. found that pure vermiculite (no interstratified mica present) does not show the wormy threads when rapidly heated. See vermiculite

ion Atoms or molecules become ions by the gain or loss of electrons, which have a negative charge. A positively charged ion, or cation, involves a loss of one or more electron(s). A negatively charged ion, or anion, involves a gain of one or more electron(s).

intumesence an irreversible expansion of a solid upon heating. Vermiculite commonly shows expansion upon rapid heating (intumesence) owing to the loss of interlayer H_2O at relatively low temperatures and the separation of the layers. Slow heating of vermiculite may produce worm-like threads, and it is this characteristic that gives the vermiculite group its name: *vermiculari*, to breed worms, in Latin.

ion exchange see cation exchange

ion-dipole interaction a fluxional bond formed between an ion and a polar molecule. The classic example is where water molecules hydrate a sodium cation. However, the interaction is not restricted to H_2O, as many polar organic molecules will form ion-dipole interactions. See fluxional bond.

ionic potential the ratio (I_p) of charge (z) on an ion to the radius (r) of the ion, $I_P = z/r$.

isoelectric point (iep) see point of zero charge

isometric see crystal system

isomorphic see isomorphous

isomorphous Isomorphous literally means "having the same form". The idea was first described by F. Beudant around 1800 (see Zoltai and Stout, 1984, p. 5-6) to describe crystals having the same form but having compositions between $FeSO_4$ and $ZnSO_4$. Thus, the term subsequently became commonly used to describe a series of crystals having continuously varying composition even where crystal faces are lacking. Such homogeneous chemical mixtures display a continuous range of properties, e.g., from the Fe to Zn end members. Such a series of solids is referred to as an "isomorphous substitution" series (archaic) or "solid solution" series. See "solid solution" for additional discussion. Isomorphic (syn)

isotropy a description of material with physical properties that are the same regardless of direction of measurement. *Cf.*, anisotropy

K-bentonite see bentonite

K0 condition see at-rest condition

kandite discredited term, use kaolin-serpentine group (Bailey, 1980)

kaolin a) Petrologic term: rock composed primarily of kaolinite, nacrite, dickite, or halloysite (i.e., minerals of the kaolin group). In most case, the identification of the specific species is unknown. The rock is commonly white, earthy, and soft. b) Mineralogic term: a sub-group name (within the group "serpentine-kaolin") for those phyllosilicates that are dioctahedral, with 1:1 layers, and with a net layer charge of approximately 0.0. Species of this sub-group include kaolinite, nacrite, dickite and halloysite. Previously, the group name was "serpentine-kaolinite", and the subgroup name was "kaolinite", but this scheme created confusion because it was unclear if "kaolinite" was referring to the more general sub-group or the species "kaolinite". See also Part 2 of the Glossary. *Cf.*, dioctahedral, 1:1 layers

kaolin, hard a white to gray clayey-textured rock predominantly composed of kaolin group minerals (primarily kaolinite). Hard kaolin is fine grained, difficult to break, and commonly with sharp, protruding (jagged) edges. Hard kaolin requires more complex mine extraction and mineral processing techniques than "soft kaolin" (kaolin-rich rock that is smooth to the touch, weak, and friable).

kaolin, soft see kaolin, hard

kaolinite subgroup superceded by kaolin subgroup

kaolinite-serpentine group superceded by kaolin-serpentine group

Kaopectate® a commercial product (made by Chattem, Inc.) involving a formulation of kaolin and pectin that was used as an anti-diarrheal. Since 2003, the formulation was changed to bismuth subsalicylate, but some formulations containing attapulgite as the active principle are sold in Canada.

Keggin ion An aluminum-rich Keggin-type structure is commonly used as a pillaring agent in clays. This complex has a composition of $Al_{13}O_4(OH)_{24}(H_2O)_{12})^{7+}$, and is often referred to as Al13. Other compositions with the Keggin structure are possible, but they have not been as extensively studied in pillared clays. Keggin structures are of commercial interest because they are catalysts. See pillared clay.

Kelvin A temperature unit where one K equals 1/273.16 of the thermodynamic temperature of the triple point of pure water, which is the temperature at which ice, water and water vapor can coexist in thermodynamic equilibrium (definition from the 13th Conference of the Générale des Poids et Mesures). 0 K, termed “absolute zero”, is the temperature at which atoms do not thermally vibrate. *Cf.*, Celsius, Fahrenheit

kiln, rotary a furnace having an inclined rotating tube which is heated either directly (a flame or heater within the furnace) or indirectly (inductively from outside). Rotary kilns are often used in industrial applications to achieve dynamic heating of raw materials to form reactive components, such as metaclay or clinker for Portland cement. The temperature and the dwell time can typically be set in each furnace segment, the latter by installing shovels or by changing the inclination or the rotational speed of the tube. *Cf.*, metaclays, clinker

kinetics see chemical kinetics

Kübler index Kübler (1964, 1967) attempted to define a “crystallinity” index for illite (“IC”) by examining the powder X-ray diffraction of intergrown illite and muscovite, originally to identify the anchizone (diagenesis) and the anchizone-epizone (metamorphic) boundaries. Measured values are expressed as small changes in the *d* value based on the width for the 10-Å peak at half height above the background for Cu radiation. If the procedure is used, it should not be characterized as a “crystallinity” index, as it is unclear if “crystallinity” is actually being measured because such patterns also reflect the presence of smectite and other K-rich micas, different mean crystallite sizes, lattice strain, layer stacking order, instrument parameters and other features. *Cf.*, crystalline, crystallinity index, Hinckley index, Arkai index

laminae see lamination

laminar microfabric see microfabric, clay

lamination sequences of thin bedding (or “laminae”) occurring because of variations in the sediment supply in sedimentary rocks. Potter et al. (2005) suggests that laminae are <1 cm.

Laponite® Laponite is a synthetic clay mineral with a hectorite-like composition, $Na_{0.7}Si_8Mg_{5.5}Li_{0.3}O_{20}(OH)_4$, and structure. Laponite is manufactured by BYK Additives &

Instruments to modify the rheology of aqueous fluids. Laponite-S482 is a common excipient in pharmaceuticals.

lattice parameters see cell parameters

lattice a collection of equivalent points (i.e., identipoints) which are distributed periodically in space, and this term, in three dimensional space, commonly refers to Bravais lattices. From Guggenheim *et al.* (2006) and references therein. The term "layer lattice" is incorrect because it implies a structure rather than a lattice. *Cf.*, array, Bravais lattice, identipoint, structure

lattice misfit A lattice misfit is where there are (one or more) dimensional mismatches between a substrate crystal and an overgrowth crystal that has formed by heterogeneous nucleation. A lattice misfit parameter, d, may be calculated from $d = D_a/a$, where a is the lattice parameter of the (stress-free) substrate crystal, and D_a is the difference in lattice parameters between the underlying substrate and the overgrowth precipitate. *Cf.*, epitaxy, lattice

layer displacement the sum of the intralayer displacement plus the interlayer displacement, which defines the total relative displacement between adjacent layers, as shown in Figure 1. For 2:1 layers, the layer displacement is measured from the geometric center of the ditrigonal ring. The "intralayer displacement" is the shift that originates from the octahedral slant within one layer and is measured from the geometric center of the ditrigonal ring from the lower to the upper tetrahedral sheet of that layer (Figure 1). Layer displacement should be used instead of "interlayer shift". *Cf.*, interlayer, layer

layer charge In phyllosilicates, the "layer charge", "net layer charge", or "permanent layer charge" is the total negative charge deviation from an ideal, unsubstituted dioctahedral or trioctahedral composition. In addition, phyllosilicates may have other charge effects on their surface, commonly referred to as the "variable layer charge".

For example, for an R^{3+}-rich dioctahedral 2:1 layer, the layer composition is ideally: $R_2Si_4O_{10}(OH)_2$. In muscovite mica where R = Al and there is an Al substituted Si site, the layer composition is: $Al_2(Si_3Al)O_{10}(OH)_2$ and because an Al^{3+} substitutes for an Si^{4+}, there is an unsatisfied residual charge on the layer that results, a layer charge of -1. In muscovite, this residual charge is compensated by an interlayer cation, K^+, so that the structure is charge neutral. Because of the anion framework of $O_{10}(OH)_2$, layer charges are always negative, but may be reported in the literature as either a positive or a negative value. A negative layer charge results from either a solid solution where a cation of lesser positive charge substitutes for a cation of greater charge or by a vacancy (no charge) substitution for a cation. Anion substitutions [e.g., O for (OH)] are also possible but uncommon. The location and size of the substitution has a profound effect on the physical properties of clays. The layer charge is used in the classification scheme for phyllosilicates.

The variable layer charge depends on the pH of the suspension. Assuming a simple pK model, low pH values lead to protonation of the surface species OH^0 group located at the edges or the surface and hence, to a positive variable layer charge of OH_2^+. Increasing pH values may lead to deprotonation and hence, to a negative variable charge of O^-. The pH point where the net charge of the entire particle is zero (e.g., for a clay mineral, the positive variable change is equal to the negative permanent charge) is called "point of zero charge" (pzc). See point of zero charge.

layer For phyllosilicates, a layer (see Fig. 1) contains one or more tetrahedral sheets and an octahedral sheet. There are two types of layers, depending on the ratios of the component sheets: a "1:1 layer" has one tetrahedral sheet and one octahedral sheet, whereas a "2:1 layer" has an octahedral sheet between two opposing tetrahedral sheets. *Quot* Guggenheim *et al.* (2006); also see references therein. *Cf.*, plane, sheet, tetrahedral sheet, octahedral sheet

layer double hydroxides see double metal hydroxides

layer-by-layer composite composites produced on nearly any substrate, including textiles, where the composite is fabricated by successive dipping/rinsing/drying of the substrate in two different solutions, one solution containing a clay, usually montmorillonite, and the second solution containing a complimentary polymer (e.g., any polycationic polymer). These composites are typically transparent, and generally 40 to 50 bilayers thick. Layer-by-layer composites lower flammability substantially and improve gas barrier properties. See flame retardancy

LDH see double metal hydroxides

lean clay see fat clay

Lennard-Jones potential a description of the interactive forces occurring between a pair of neutral atoms or molecules. The potential is comprised of force-field terms: at long-separation distances, van der Waals attraction predominates, whereas at short-separation distances, strong repulsion predominates as a result of the Pauli exclusion principle. The Lennard-Jones potential is accurate for noble gas interactions and a relatively good model for most neutral atoms and molecules. The Lennard-Jones potential is computationally simple and thus commonly used in modeling programs.

LHC see liquid holding capacity

ligand see complex

limestone a crystalline sedimentary rock mainly composed of $CaCO_3$. Common minor constituents include quartz, feldspars and clay minerals. Limestone is heated to make clinker which is an additive to make Portland cement. *Cf.*, clinker, Portland cement

line defect A line defect involves a series of structural imperfections that produces a linear feature and, commonly, offsets or "dislocations", within an atomic structure. An "edge dislocation" forms where a plane of atoms or ions that would normally extend throughout the crystal terminates along a line within the crystal. Distortions are at a maximum along the line of termination. A "screw dislocation" is a localized screw axis involving atoms or ions (or blocks of atoms or ions) to form a spiral, much like a spiral staircase, with a step at the outer surface of the crystal. Because the screw dislocation is a local feature, the screw axis is not related to the space group (overall symmetry) of the structure, and the crystal regains its overall atomic periodicity at distances further from the central line of the dislocation. The step at the surface of the crystal is believed to enhance crystal growth because atoms or ions can better adhere and bond to sites associated with greater surface area at the step. *Cf.*, point defect, screw axis

liquid holding capacity the maximum capacity that a fine-grained, porous, granular material can absorb a liquid into the pore structure of the individual grains and still remain free-flowing. The point where the liquid impregnated granules adhere to the sides of a container (i.e. become "wetted") represents a rough measure of internal liquid holding capacity of the material (i.e., the point beyond where granules begin adhering together and lose free-flowing properties).

liquid limit one of the Atterberg Limits tests. The water content of a fine-grained soil/water mixture that defines the boundary between the liquid and plastic states for that soil, as defined by the test method described in ASTM Standard D4318 - 05. See Mitchell (1993). See also activity, Atterberg Limits, consistency number, plastic limit, plasticity index, shrinkage limit.

liquidity index (water content – plastic limit) ÷ index of plasticity, or: $(w - w_{p)} \div (w_l - w_{p)}$. See also Atterberg Limits, plastic limit.

liquidus a term describing the lower limit where only a liquid phase exists in a phase diagram. *Cf.* Phase diagram, solidus

lithomarge a sectile and compact kaolin clay when wetted, often white to red/pink in color and mottled. When dry, lithomarges are friable.

loam a yellow-brownish or brown soil mainly composed of sand (>63 µm size, <52% content), silt (2 - 63 µm size, 28 - 50% content), and clay (<2 µm size, 7 - 27% content). Loam commonly exhibits low carbonate contents, but a high nutrient and water content and hence, loam is an excellent plant substrate. Additionally, loam can be used in the building industry to form bricks.

LOI see loss on ignition

loss on ignition (LOI) weight loss after heating, and (usually) subsequent cooling, to determine the presence of volatiles in a solid. *Cf.*, water, structural; water, adsorbed

low volatile matter (LVM) an industrial term referring to superheated but not fully calcined clays. *Cf.*, superheating

low-activity clay In geotechnical engineering, low-activity clays have activities of < 1, and include illite, chlorite, and kaolinite. Fe and Al oxide minerals and clay-sized primary minerals are also considered low activity. See activity, clay; high-activity clays; quick clays

lumen a) Industrial/clay: A lumen is the bore of a tube. Thus, halloysite is a tubular mineral with an approximately 30 nanometer diameter lumen that runs the length of the tube. b) Medical: A cavity of passage in a tubular organ; e.g., the lumen of the intestine. Also, commonly applied to those clay minerals where medications are loaded into the tube bore, and the clay particle is coated with an excipient to control the timing of delivery.

luster appearance of a mineral surface in reflected light

lutite Lutite is an older field term for an argillaceous, fine-grained rock that is equivalent to claystone and mudstone. In clay mineralogy, the term "lutite" is commonly applied to authigenic clays. An equivalent term is "argillite".

LVM see low volatile matter

macronutrient a general term for major dietary nutrients required in relatively large quantities per day. For example for human consumption, macronutrients include Ca K, Na, Mg that may be potentially provided by ingestion of clays, whereas clays in soils provide these nutrients for plants. *Cf.*, micronutrient

macropore In clay science, a macropore (Figure 3) is a cavity among clay particles or aggregates with a diameter of >50 nm, in accord with IUPAC convention (Rouquerol et al., 1994). In soil science, a macropore is defined as a cavity among aggregates with a diameter of >75 µm (Soil Science Society of America, 1997). The pore volume (or pore size) distribution of clays is commonly determined by gas adsorption methods (typically H_2O or N_2), whereas in soil science/physics, it is usually determined by mercury intrusion porosimetry (MIP) technique. *Cf.*, mesopore, micropore

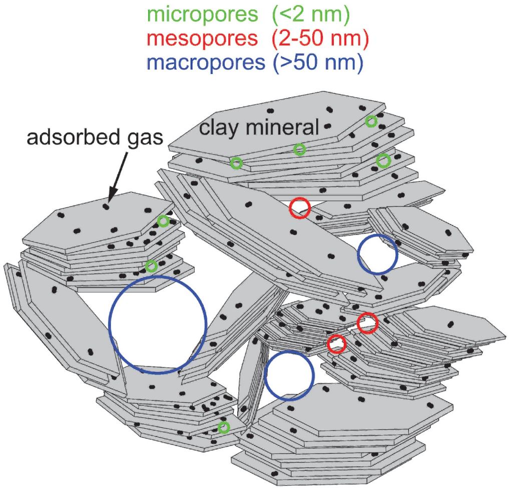

Figure 3. Schematic illustrating micropores, mesopores, and macropores in an aggregate of clay mineral particles. Whereas macropores occur between stacks of clay particles, micropores exist at the edges of clay particles and stacks, often relating to partially bent edges, translational disorder, and/or rotational disorder. Adsorbed gas molecules are illustrated by nitrogen molecules, a common gas used for gas adsorption methods.

mafic a geological term describing magmas, igneous rocks and silicate minerals that have a relatively high concentration of magnesium and iron and a low silica concentration. Mafic magmas typically have low viscosity, when compared to felsic magmas. Mafic rocks are typically darkly colored when compared to felsic rocks. *Cf.,* felsic

magnetic susceptibility the ratio of the magnetization, *M*, relative to the macroscopic magnetic field intensity, *B*. "Diamagnetic" substances have negative values, "paramagnetic" substances have positive susceptibilities. *Cf.*, diamagnetism, paramagnetism

magnetism describes a property of material where there is attraction by a magnet. Cf., diamagnetism, paramagnetism

mangan see cutan

marl an unconsolidated, soft sediment primarily composed of calcium carbonate, lime, and/or clay; impurities are common. Marl is formed in marine and lake deposits as a mud. Marl is used as a fertilizer to enhance calcium content and as a component of Portland cement.

matrix see clay groundmass

matrix microfabric see microfabric, clay

matured muds see peloid

maximum consolidation stress/pressure see preconsolidation pressure

MC see Monte Carlo molecular simulation

MD see molecular dynamics

mean square displacement a representation of the average (squared) distance traveled by an atom or particle during a defined period of time at a specific temperature. In a molecular dynamics simulation, the mean square displacement is used to calculate the diffusion coefficient for a given atomic or molecular species (e.g., interlayer cation or H_2O). In an atomic structure determination, the mean square displacement describes the time averaged movement of an atom about its mean equilibrium position at a given temperature. This "movement" involves not only (dynamic) thermal vibrations, but also an apparent movement caused by (static) disorder from the random distribution of atoms over different equilibrium positions at (or near) a site from all the unit cells sampled in the experiment (where perfect periodicity is lacking in a crystal). *Cf.*, density functional theory, Grand Canonical Monte Carlo simulation, molecular dynamics, Monte Carlo molecular simulation, quantum calculation

medicinal clays a general term for a clay used as an active principle or excipient ingredient in medication. *Cf.*, active principle, aesthetic medicine, antibacterial clay, geotherapy, healing clay, pelotherapy

mesopore In clay science, mesopores (Figure 3) are cavities with diameters of 2 - 50 nm within a clay sample in accord with IUPAC convention (Rouquerol et al., 1994), although in soil science mesopores are defined as between 30 - 70 μm (Soil Science Society of America, 1997). In clays, these pores are present between mineral stacks of several unit structures. The pore volume (or pore size) distribution of clays is commonly determined by gas adsorption methods (typically H_2O or N_2). *Cf.*, macropore, micropore

metaclay see thermally activated clay

metakaolin kaolin material that has been heat-treated to partial or complete dehydroxylation. *Cf.*, dehydroxylate, dehydroxylation, thermally activated clay

mica a general term for platy phyllosilicates of 2:1 layer and a layer charge of ~ -1.0 per formula unit (true mica group) or ~ -2.0 per formula unit (brittle mica group) or between -0.6 to -0.85 per formula unit (interlayer-cation-deficient mica group, abbreviated to interlayer-deficient micas). Micas do not show swelling capability. Octahedral character, either trioctahedral or dioctahedral, further divides the mica groups into subgroups, whereas chemical composition separates the species within the subgroups. *Cf.*, true mica, brittle mica, interlayer-deficient mica, group names

micaceous A mineral habit where individual grains are platy in shape, as often caused by a single plane of cleavage**.** *Cf.*, habit

micelle an aggregate of surfactant molecules (each molecule consisting of a non-polar hydrophobic tail and polar hydrophilic head) dispersed as a liquid colloid. In aqueous solutions, a micelle forms with the tails oriented inward and the heads facing outward to solution.

Michaelis-Menten kinetics equation The Michaelis-Menten kinetics equation describes the kinetics of many enzyme-catalyzed reactions and involves an enzyme binding to a substrate to form a complex. This complex produces a product and additional enzymes, which produces more complexes with a consequential increase in the reaction rate. The equation has been successful in describing the rates of many biochemical reactions (e.g., protein-protein reactions) other than in complexes involving enzyme binding substrates.

microcomposite, organoclay an organoclay with at least one dimension in the micrometer range dispersed in a polymer. *Cf.*, organoclay, organoclay nanocomposite

microcrystalline see cryptocrystalline

microfabric, clay Clay microfabric is the description of the spatial distribution of clay particles in either clay-rich rock or sediment, commonly observed directly by electron microscopy of aggregates, domains, or layer stacking effects within the material. Microfabric variations may affect physical properties, conditions of formation, and evolution of the material. See Bennett et al. (1977) and Potter et al. (2005) and see microstructure. Types of clay microfabric are (after Grabowska-Olszewska et al., 1984):

domain microfabric A domain microfabric is composed of unoriented, coarse domains of kaolinite crystals with parallel axial orientation. Domain boundaries involve face-to-edge and edge-to-edge particles. Pore shapes are complex, with equidimensional interdomain pores (2-8 μm in diameter) and smaller fissure-like intradomain pores (<0.5 μm). This microfabric is characteristic of eluvial kaolinitic clays; domains often form from weathered feldspar crystals.

honeycomb microfabric Honeycomb microfabric consisting of unoriented, high porosity (60-90%), nearly equidimensional cells or domains commonly 2 - 12 μm in size in sedimentary clay-rich soils. Cell walls are comprised of microaggregates of face-to-face and face-to-edge clay particles of montmorillonite-illite mineralogy. Silt/sand grains are rare and are distributed throughout the soil. Most cell contacts are of flocculation type (clumping of small particles), which promotes the high porosity. The fabric is syngenetic (i.e., formed during sedimentation) and forms in recent marine and lacustrine sediments.

laminar microfabric A sedimentary clay soil with a laminar-flow appearance from well developed bedding/sorting of its structural components, mostly microaggregates with face-to-face, and occasional face-to-edge, boundaries. Pores between aggregates are fissure- and wedge-shaped parallel to the lamination. This microfabric is common of clay-rich deposits (>50%) of varying mineral composition and forms in syngenetic and/or post-depositional environments.

matrix microfabric A microfabric characterized by a continuous unoriented clay matrix with a non-uniform distribution of silt/sand grains. The clay (illitic and mixed-layer particles) forms microaggregates with face-to-face, face-to-edge, and edge-to-edge boundaries. Pore sizes range from 8 to 2 μm for poorly compacted and compacted sediment/soil respectively. Formation can be syngenetic and/or post-depositional.

pseudoglobular microfabric Pseudoglobular microfabric is formed by the weathering of iron-rich igneous or metamorphic rocks with neoformation of iron phyllosilicates (e.g., nontronite). This microfabric contains spheroidal microaggregates ranging in diameter of 5 - 20 μm, sometimes composed of sheet-like particles with face-to-edge contacts or with face-to-face and face-to-edge interactions. Porosity is made of equidimensional interglobular (10 - 15 μm) and equidimensional or elongate intraglobular voids.

skeletal microfabric Skeletal microfabric is comprised of a generally uniform, porous structure of unoriented silt/sand grains (to 60%) and clay (10 - 30%), the latter forming a discontinuous matrix and commonly accumulating along the larger-grain boundaries to tenuously bond the grains together. This microfabric is more compact than the honeycomb microfabric with porosities ranging from 40 - 60%. The skeletal microfabric occurs more commonly in recent clay deposits of varying mineral composition (but often illitic). Formation can be syngenetic and/or post-depositional.

sponge microfabric Sponge microfabric consists of coarse aggregates (> 80 μm in diameter) of sheet-like microaggregates with mostly face-to-edge and face-to-face contacts, forming a continuous fine-cellular network resembling sponge. The clay material is not orientated and pores are irregular in shape and < 3 μm in size. For example, this microfabric has been reported in smectite clays of hydrothermal origin. See microfabric, microstructure

turbulent microfabric A microfabric with a turbulent-flow appearance derived from clay microaggregates that are well oriented along deformed laminations of clay-coated silt/sand grains within a matrix of deformed bedded clay. Clay microaggregates are bounded by face-to-face clay particles, and locally, by face-to-edge contacts at very small angles. The clay content is > 20%. The pores are primarily fissure-like and elongated along the lamination. This microfabric is commonly formed during the diagenesis (compaction) of clay sediments with precursors of honeycomb and matrix microfabrics.

micrometer (µm) an International System (SI) unit of measure equal to 10^{-6} meters.

micron (µm) an old name for micrometer

micronutrient a general term for dietary essential nutrients required in relatively small amounts (less than 50 milligrams per day). For example, micronutrients include vitamins (organic compounds) and trace elements (e.g., Fe, Cu, Zn, I, Se, Mn, Mo, Cr, F, Co) for human consumption that may be potentially provided by ingestion of clays, whereas clays in soils provide these nutrients for plants. *Cf.*, macronutrient

micropore In clay science, micropores (Figure 3) are cavities with diameters of <2 nm within a sample, following the IUPAC convention (Rouquerol et al., 1996), which is also similar in size to a common (upper) clay particle size used in clay studies. Thus, these pores are probably present at the edges of single stacks of unit structures and at widened edges of the interlayer. In soil science, micropores are defined as 5 - 30 µm, ultramicropores are 0.1 – 5 µm, and cryptopores are <0.1 µm (Soil Science Society of America, 1997). The pore volume distribution of clays is commonly determined by gas adsorption methods (typically H_2O, N_2 or, CO_2). *Cf.*, macropore, mesopore

microstrain In clay science and materials science, microstrain is a local strain caused by a local deviation of the lattice parameters from the mean value. Microstrain originates by 1) atomic substitutions where the ionic radius of the substituting ion differs from the original ion, 2) missing atoms or ions in the structure, 3) interactions with neighboring crystallites having slightly different lattice parameters, e.g., owing to twinning, an inhomogeneous mixture of crystallites with similar lattice parameters. In X-ray diffraction patterns, microstrain causes peak broadening. A microstrain expression is defined as the root-mean-square of the lattice parameters. In physics, mechanics, and many engineering disciplines, microstrain is a strain expressed in terms of parts per million (10^{-6}), where strain is defined as a ratio of the change in the distance/dimension to the original distance/dimension, and hence it has no unit and is dimensionless.

mineral an element or chemical compound that is normally crystalline and that has been formed as a result of geological processes (*quot* Nickel, 1995). A mineral forms by a naturally occurring process (e.g., "geological" process); phases formed by the interaction of individuals (even if outdoors under conditions not fully controlled by the individual) are not minerals. Nickel (1995) discussed exceptions to the requirements, such as the equivalence of extraterrestrial and "geological" processes, metamict (non-crystalline) minerals, mercury (a liquid mineral), and others (*quot* Guggenheim et al., 2006). Some naturally occurring processes, but without a geological component, such as compounds that form biologically (e.g., oxalate crystals in certain plants, marine animal shells), are not minerals. Synthesized materials are not minerals, but may be referred to as “synthetic minerals” (e.g., “synthetic diamond”, “synthetic halite”) because the use of “synthetic” negates the naturally occurring/geological aspects specifically. Likewise, “biomineral” is acceptable for similar reasons as synthetic mineral. See crystalline, *Cf.,* biologically controlled mineralization, biologically induced mineralization, biomineralization

mineraloid a natural solid with insufficient long-range atomic ordering to be classified as a mineral. For example, limonite ($FeO \cdot OH \cdot nH_2O$) is often considered an amorphous “mineral” or mineraloid.

mirror plane or symmetry plane, used to describe a repetition of features whereby identical points occur an equal but opposite distance along any line perpendicular from this imaginary plane. Consequently, an object is “bilateral” in that it shows a matching of features (also referred to as “reflection”) but a change in “handedness”, e.g., most people, standing with arms by their sides and feet side-by-side, have a mirror (bilateral or reflection) relationship between the left side and the right side. *Cf.*, symmetry, center of symmetry, rotation symmetry

Mississippi bentonite an obsolete term, see Southern bentonite

mist see suspension

mixed layer see interstratification

Mohr’s circle Mohr’s circle is a two-dimensional graphical representation of the three-dimensional state of stress of a soil element subject to load in the normal stress - shear stress coordinate system. Components (i.e., orientations of the normal and shear stresses) of applied stress may be graphically obtained across various inclined planes at a given point in a stressed body. *Syn.*, Mohr circle of stress, stress circle

Mohs hardness Mohs’ scale of hardness is composed of a series of common minerals with increasing hardness: (1) talc, (2) gypsum, (3) calcite, (4) fluorite, (5) apatite, (6) orthoclase, (7) quartz, (8) topaz, (9) corundum, and (10) diamond. Hardness is determined by a scratch test, as minerals of greater or equal hardness can scratch those of equal or lesser hardness. *Cf.*, hardness, Vickers hardness

moisture content see water content, degree of soil

molality the number of moles of solute per kilogram of solvent. Because weights of a solute/solvent are generally fixed at all temperatures, this scale is useful for experiments where physical properties (e.g., boiling point, freezing point) are examined over a temperature range. *Cf.*, molarity, formality, normality, mole fraction

molarity the number of moles of the solute in one liter of solution. Useful where experiments use measured volumes and where temperature effects are not being studied. *Cf.*, formality, normality, molality, mole fraction

mole fraction number of moles of one component divided by the total number of moles of all components *Cf.*, molarity, formality, normality, molality

molecular sieve see zeolite, pillared clay

molecular dynamics (MD) a molecular simulation for calculating time-averaged properties of a molecular system. The model system is simulated by solving Newton's equations of motion, including kinetic and potential energy terms. The energy terms can be obtained by using classical (force field) or quantum (Density Functional Theory) methods. System constraints (e.g., constant volume, temperature, pressure) usually correspond to a thermodynamic ensemble. *Cf.*, density functional theory, force field, Grand Canonical Monte Carlo simulation, Monte Carlo molecular simulation, quantum calculation

molecular orbital method a method of calculating the electronic structure and related properties of a finite molecular system consisting of two or more atoms by solving the Schrodinger equation to determine the electronic structure. Various methods exist to approximate the simultaneous solution of the Schrodinger equation for all electrons in the molecular system.

molecular simulation a set of computational methods used to calculate physical or chemical properties of a model system consisting of atoms or molecules. Computed properties can include chemical reactions, structure, spectroscopy, and transport. Many techniques exist for such simulations based on model system size and desired accuracy, from quantum methods to classical (force field) methods. *Cf.*, force field, quantum calculations

molecularity the number of reacting molecules, atoms, or ions in a single-step chemical reaction. For example, a unimolecular reaction may involve radioactive decay of a single atom, or one molecule producing other molecules. A bimolecular reaction involves the collision and reaction between two molecules, atoms or ions to form other products. *Cf.*, Transition State Theory

monic c/f-related distribution see c/f-related distribution

monoclinic see crystal system

monolayer, phyllosilicate Between 2:1 layers of a phyllosilicate, a monolayer involves an arrangement within the interlayer of one single plane of H_2O molecules around interlayer cations (= hydration shell). Although the plane is only approximate, the spacing seems to suggest a planar feature. Because the H_2O molecules are in planar coordination around the cation, the spacing appears as an H_2O plane or "layer". *Cf.*, bilayer; bilayer, phyllosilicate

monolayer see monolayer, phyllosilicate

mononuclear complex see binuclear complex

monostriated b-fabric see b-fabric

Monte Carlo molecular simulation (MC) a classical molecular simulation approach, based on the Metropolis Monte Carlo algorithm, for calculating ensemble averages of structural properties. The model system evolves based on random moves (e.g., atom or molecular translation, system volume) that are accepted or rejected using a Boltzmann algorithm. System constraints (e.g., constant volume, temperature, pressure) usually correspond to a thermodynamic ensemble. *Cf.*, force field, Grand Canonical Monte Carlo simulation, molecular dynamics, quantum calculation

montmorillonite-saponite group old group name superceded by smectite. See also Part 2 of the Glossary. *Cf.*, smectite

morphology (soil micromorphology) In soil science, the geometry and surface topology of a soil particle. The term may also be used as a study of soil horizons and soil properties.

mortar Mortar is a binder used between blocks or bricks or to coat ceilings and walls. Mortar is produced by mixing lime, pozzolan, or (Portland) cement with sand or gravel and appropriate amounts of water. The hydraulic reaction of water and lime or cement determines the characteristics of the binder, such as strength and other binding properties. *Cf.*, Portland cement, cement

mosaic-speckled b-fabric see b-fabric

mottle see glaebule

muck indicates a soil composite that is largely organic in nature, lacks recognizable plant structures and is very darkly colored. It differs from peat in being darker, lacking plant structures and having increased mineral content. It differs from ball clay in having significantly higher organic content and in being much darker.

mud soft, plastic, sticky or slippery matter, generally containing water and clay minerals derived from fine-grained soil/regolith/sediment materials. Mud is commonly composed of clay-size particles, but often contains mixtures of sand- and silt-size particles as well as microorganisms. Potter et al. (2005) considers mud a sedimentological field term for unconsolidated fine-grained sediments of any composition and consisting of 50% or more of particles smaller than 0.0063 mm (i.e., clay and silt size fractions). *Cf.*, see geotherapy, matured mud, pelotherapy, poultice, Udden-Wentworth scale

mud therapy therapeutic use of healing mud (hydrated clay) in an empirical way and without medical supervision for palliative or cosmetic purposes. Traditionally, mud therapy was practiced in the natural environment where the mud occurs, but this is no longer the case. Also, see aesthetic medicine, antibacterial clay, geotherapy, healing clay, pelotherapy, peloid

mudrock An indurated, sedimeantary clay-bearing rock with 33-65% clay-size constituents and stratification of >10 mm thickness (bedding). An individual mudrock bed may be internally massive (after Potter et al., 2005). See clayshale, claystone, mud, mudstone, mudshale, silt, siltstone.

mudshale An indurated, sedimentary clay-bearing rock with 33-65% clay-size constituents and lamination (stratification of <10 mm thickness), after Potter et al. (2005). See clay, clayshale, claystone, mud, mudstone, mudrock, silt, siltstone.

mudstone A general term for a rock which is similar to shale but used to describe a clay-rich rock without laminations. The fraction of clay and/or silt components are not well defined. The silt component may be of major proportions. See clay, clayshale, claystone, mud, mudrock, mudshale, silt, siltstone.

mull In soil science, mull is a type of humus of the A horizon, without distinct layering, and composed of organic matter intimately mixed with the fine-grained mineral fraction. *Syn*., mull humus

nanocomposite, organoclay an organoclay with at least one dimension in the nanometer range dispersed in a polymer (e.g. nylon-6 clay-nanocomposites; see Gilman et al.,1997). The less hydrophilic surface of organoclays facilitates dispersion in a polymer. Dispersing ~5% organoclay in a polymer can make the polymer more flame retardant and improve the physical properties. See Gilman et al., 1997; Picken et al., 2008; Ruiz-Hitzky and Van Meerbeek, 2006. *Cf*., organoclay, organoclay microcomposite

nanocomposite Nanocomposites are fine-particulate materials that are heterogeneous at the nanoscale level (i.e., less than 10^{-7} meters). Such materials have structures and properties that are composite-particle-size dependent. The composite-particle size is sufficiently large that it is not considered a chemical (atom) cluster or complex.

nanotube a natural or man-made, nanometer-scale tubular structure. See nanocomposite, imogolite.

nanometer (nm) an international system (SI) unit of measurement equal to 10^{-9} meters**.**

natural peloid see peloid

Néel temperature see antiferromagnetism

neo-cutan see hypo-coating

neoformation The phenomenon by which secondary minerals are formed by crystal growth entirely from solutes without any incorporation of pre-existing structural components from other preexisting (parent) minerals. See inheritance, transformation

Nernst Equation a model to determine the equilibrium reduction potential of a half-cell in an electrochemical cell, such that $E_{red} = E^{o}_{red} - (RT/zF)\ln(a_{red}/a_{Ox})$, where E_{red} = half-cell reduction potential, E^{0}_{red} = standard half-cell reduction potential, R = ideal gas constant, T = absolute temperature, z = number of electrons transferred in the half-cell, F = Faraday constant, a_{Red} = activity of the reduced species, and a_{Ox} = activity of the oxidized species. An alternative form of the equation can be used for the total cell potential where $E_{cell} = E^{o}_{cell} - (RT/zF)\ln Q$, where E_{cell} is the cell potential or electromotive force, E^{0}_{cell} is the standard cell potential, Q is the reaction quotient, and the other parameters are given above. The Nernst equation is most useful for dilute solutions because concentrations are approximately equal to activities. The equation only applies where there is no current flow at the electrode and also because concentration is approximately equal to activity. Otherwise, corrections must be applied.

net layer charge see layer charge

Newtonian fluid a fluid where the viscosity, equal to the ratio of shear stress to shear rate, is constant. A Newtonian fluid is approached in suspensions of water and clay where the clay is fully defloculated. *Cf.*, dilatancy, quick clay, thixotropy

nodule see glaebule

non-crystalline a solid where the constituent components are randomly packed. Many variations can occur between the two extremes of crystalline *vs.* non-crystalline. For example, a non-crystalline material, such as many glasses, consists of atoms arranged as groups of tetrahedra or octahedra. However, although such groups have almost the same mutual arrangements, they are displaced without periodicity with respect to each other (i.e., limited order or short-range order). (*Quot* Guggenheim *et al.*, 2006) *Cf.*, crystalline

normal mode the correlated motion of atoms in a molecule or crystal identified by a specific frequency and with the same phase relations in the vibrational spectrum. The symmetry of the normal mode is related to the symmetry of the molecule or crystal. *Cf.*, vibrational spectroscopy

normality the number of gram equivalent weights of the solute in one liter of solution. Useful where experiments use measured volumes and temperature effects are not being studied. *Cf.*, molarity, formality, molality, mole fraction

normally consolidated clays a clay mass that has been compressed by the stress expected from just overburden, without any previous overloading. *Cf.*, preconsolidation stress, overconsolidation ratio

obliquity the ratio of the major principal effective stress to the minor principal effective stress among three orthogonal planes at any stressed point, where there are zero shear stresses.

octahedral sheet For phyllosilicates, an octahedral sheet contains edge-sharing octahedra that are connected in a continuous two-dimensional arrangement. These octahedra generally contain small (e.g., Al, Fe^{3+}) or medium size (e.g., Mg, Fe^{2+}, Li) cations with coordination anions (e.g., O, OH, Cl, S). In some phyllosilicates (e.g., modulated phyllosilicates), the octahedral sheet may be only partially continuous, for example, forming one-dimensional strips of octahedra or islands of octahedra. There are two types of octahedral sheets, dioctahedral and trioctahedral. After Guggenheim *et al.* (2006) and references therein. *Cf.*, dioctahedral sheet, trioctahedral sheet, plane, layer

octahedral layer inappropriate usage for an octahedral sheet, see octahedral sheet

oedometer a one-dimensional, consolidation testing apparatus commonly used to measure the compressibility and consolidation behavior of soft clayey soils. In such tests, the soil is confined to one-dimensional compression and one-dimensional flow. Only vertical deformation or strain occurs, whereas the lateral or horizontal deformation is restricted or zero.

oligomer An oligomer is a chemical compound composed of a small number of structural units (e.g., AlO_4 or SiO_4 tetrahedra) formed by a polymerization process, typically with carbon or aluminum atoms, where smaller units are bound together to form larger units. According to IUPAC, a minor change in the number of integrated units causes a significant change in the properties of the oligomers and distinguishes them from polymers that consist of large numbers of structural units. Small oligomers composed of only a few units include: monomer = 1 unit, dimer = 2 units, trimer = 3 units, tetramer = 4 units, etc. Oligomers are found in synthetic clay-related products (e.g., geopolymers) or naturally occurring clay minerals (e.g., hydroxy-interlayered clay minerals often contain oligomers in the interlayer). *Cf.*, geopolymer, hydroxy-interlayered minerals, polymer, polymerization

organan see cutan

organic clay In civil engineering, an organic clay is a clayey soil containing a specific range of organic matter content (ASTM Standard D2487). Organic clay is usually distinguished by determining the change in the liquid limit of a clay that was oven-dried at 105 - 110 ºC. If the ratio of the liquid limit of the oven-dried clay to that of the natural (i.e., without oven drying) clay is < 0.75, then the soil is classified as organic clay. *Cf.*, liquid limit, organoclay, organic soil

organo-peloid see peloid

organoclay, adsorptive Based on organic contaminant adsorption isotherms and sorptive behavior, the adsorptive-type organoclays (generally producing nonlinear and Langmuir-type isotherms) have exchanged organic cations that act as interlayer props to hold the interlayer open. This arrangement facilitates additional organic contaminant adsorption onto the siloxane surfaces, which are relatively hydrophobic except near exchangeable cation sites (Chen, 1976; Jaynes and Boyd, 1991a). These clays are prepared from smectite by replacing inorganic exchangeable cations with small organic cations, such as tetramethylammonium or trimethylphenylammonium. Lower charge clay minerals (i.e., lower charge smectite) with adsorbed small organic cations yield organoclays that more effectively adsorb organic contaminants compared to the unmodified clay. See Boyd and Jaynes (1994). *Cf.*, organoclay, organophilic; organoclay.

organoclay, grafted compound-type see organoclay

organoclay, organophilic Using organic contaminant adsorption isotherms and sorptive behavior, organophilic-type organoclays (which produce simple, linear isotherms) are defined as having large exchanged organic-cation alkyl groups. These groups seem to act as a solvent phase (e.g. partitioning phase, i.e., solubilized), but are located in the interlayer, to absorb organic contaminants (Jaynes and Boyd, 1991b). a) Synthetic systems. These clays are prepared from smectite or vermiculite by using large quaternary (> C-10) organic cations, such as hexadecyltrimethylammonium (C-16) or dioctadecyltrimethylammonium (C-18). These higher charge clay minerals (e.g., vermiculite, illite, high-charge smectite) adsorb greater numbers of large organic cations and yield organoclays that are more effective in absorbing organic contaminants compared to the unmodified clay. See also Boyd and Jaynes (1994). b) Natural systems. Soil organic matter and organic compounds adsorbed to (internal or external) clay-mineral surfaces can act as a solvent phase for organic contaminants dissolved in water. Organic compounds (e.g., benzene, toluene, xylenes in gasoline) are more soluble in soil organic matter or the organic phase derived from organic compounds adsorbed to mineral particles than in water. Nonionic organic compounds may be partitioned (i.e. solubilized) into soil organic matter; see Chiou et al. (1979). *Cf.*, organoclay, adsorptive; organoclay

organoclay a phyllosilicate, typically smectite, vermiculite, or kaolin, but also other minerals (e.g., double metal hydroxides) with sorbed organic molecules, such that the properties of the mineral are altered. Commonly, the sorption occurs between the 2:1 or 1:1 layers. The mechanism for sorption may vary depending on the organic molecule and concentration. In alkylammonium organoclays, alkylammonium cations replace inorganic cations, and these organic cations are bonded to the layers via electrostatic (= Coulombic) forces. In organophilic alkylammonium organoclays where large organic cations completely fill the interlayer, van der Waals interactions between the alkyl groups augment the Coulombic forces, which increase both adsorption and organoclay stability. Adsorptive type organoclays have small organic cations that partially fill the interlayer, are stabilized by Coulombic forces, and act as pillared materials where there are accessible areas between the pillars for additional adsorption. These pillars increase surface areas relative to untreated clay or organophilic clays. In grafted compound-type organoclays with organic compounds such as silanes in the interlayer, bonding to the clay layer is covalent. Organoclays with adsorbed neutral polymers are attached to the clay layer by weak multiple dipole-induced dipole type bonds. In organoclays prepared from charged polymers, such as proteins, the polymers are bonded by both electrostatic and dipole-induced dipole bonds. Organoclays can be used as adsorbents, thickening and thixotropic agents, in nanocomposites, and in new materials with catalytic, optical, and electronic properties (Lagaly et al., Ogawa, and Dékány, 2006). *Syn.*, organo-clay, clay-organic complex; *Cf.*, organoclay, adsorptive; organoclay, alkylammonium; organoclay, organophilic alkylammonium phyllosilicate; pillared clay; phyllosilicate

organophilic a characteristic property of a clay whereby the clay can sorb an organic solvent. These clays are usually surface modified, commonly by sorbing various quaternary ammonium compounds, which allow the clay to swell in organic liquids. See organoclay, *Cf.*, organophobic

organophilic organoclay partition phase see organophilic, organoclay

organophobic a characteristic property of a clay whereby the clay repels an organic liquid. Most naturally occurring clays are organophobic and are not wetted by nonpolar organic liquids. See organoclay, *Cf.*, organophilic

orthorhombic see crystal system

osmosis, reverse The process of forcing a solvent (typically, water) through a semi-permeable membrane from a solution with lower water activity to a solution with higher water activity by applying a pressure opposite to and in excess of the osmotic pressure. Reverse osmosis is a process commonly used to purify (i.e., to physically separate and remove dissolved ions from) water.

osmosis A physical process by which a solvent (typically, water) diffuses through a semi-permeable membrane (a porous material which is permeable to the solvent, but not the solute), owing to differences in solvent activity of two solutions which are separated by the membrane.

osmotic pressure The differential pressure exerted by a solvent across a semi-permeable membrane owing to the difference in solvent activity between two solutions separated by the membrane.

osmotic swelling interlayer expansion that occurs in phyllosilicate minerals responding to the effects of temperature, pressure and composition (e.g., chemical potential) of an electrolyte surrounding the mineral with respect to the interlayer H_2O (i.e., the "osmotic effect" or "osmotic pressure"). At equilibrium, the chemical potential of H_2O in the electrolyte and in the interlayer is related to the salt concentration of the electrolyte (the osmotic pressure is zero). At a given temperature, pressure, or composition away from equilibrium, there will be a difference in chemical potential between the electrolyte and clay interlayer and the resulting osmotic pressure will be the driving force to affect the layer-to-layer distance. Under certain conditions, the resulting osmotic pressure drives the clay layers further apart than the interlayer distances common to intracrystalline swelling. *Cf.*, intracrystalline swelling

Ostwald ripening a recrystallization process where the smallest crystals dissolve and the chemical constituents are added to the larger crystals of the same phase. This process of crystal growth and coarsening occurs in a solution. The driving mechanism is a shift to lower surface free energy (Ostwald, 1900 in Baronnet, 1982).

Otay-type montmorillonite Defined by Schultz (1969) for montmorillonite samples [current nomenclature for montmorillonite is that it is an Al-rich, dioctahedral smectite with an ideal structural formula of $(Al_{3.15}Mg_{0.85})Si_8O_{20}(OH)_4X_{0.85}.nH_2O$ with layer charge from primarily octahedral substitutions of Mg] with a large net negative layer charge [-0.80 to -1.20 per unit cell, $O_{20}(OH)_4$] obtained almost entirely (<0.15 charge from tetrahedral sheet) from cation substitutions in the octahedral sheet, although exceptions were noted. This classification scheme was based on chemical and thermal analysis. The term is obsolete and should not be used. Terms used in this obsolete classification are: Wyoming-type, Otay-type, Chambers-type, Tatatila-type, beidellite-type (ideal and non-ideal), and non-ideal montmorillonite. See also Part 2 of the Glossary.

outer Helmholtz plane see *Stern layer*

outer sphere complexes Ions adsorbing in the outer Helmholtz plane form outer sphere complexes. The larger distance to the surface relative to the shorter distances of inner sphere complexes may result from retaining H_2O molecules (via hydration) between the surface and the ion.

overburden In mining, overburden refers to the unusable material(s) that is above the ore of interest. Overburden may be removed or left in place (by tunneling below it).

overconsolidation a process or phenomenon where a soil or clay mass has previously been subjected to pressures that were greater than the current overburden pressure.

overconsolidation ratio In soil science and soils engineering, the overconsolidation ratio (OCR) is the ratio of the preconsolidation effective stress to the current consolidation effective stress to which the soil is being subjected. For normally consolidated sediment the OCR = 1.0, thus for overconsolidated sediment the OCR >1.0.

palliative Palliative refers to the relief of pain (or more generally, other side effects of an illness), but without treatment of the underlying condition. Clay baths (*balnea*) are commonly used as a palliative treatment for chronic pain (e.g., arthritis).

papule A pedofeature formed by fragments of laminated clay coatings. See pedofeature.

paraffin complex see alkylammonium organoclay paraffin complex

parallel striated b-fabric see b-fabric

paramagnetism a weak magnetic attraction that develops in the presence of an external magnetic field and this attraction occurs when magnetic moments align in the material. When the magnetic field is removed, the magnetic moments (thermally) randomize and the magnetic behavior disappears. Paramagnetism is found in substances with atoms/molecules possessing an odd number of unpaired electrons. Hence, transition metals with partly filled 3*d* orbital electronic shells may show paramagnetic behavior. Thus, metals (e.g., Ti) and compounds (e.g., fayalite, augite, annite) may be paramagnetic. *Cf.*, magnetic susceptibility

paramud hydrated clays mixed with paraffin, heated to 40-45°C before topical application in a <5 cm thick layer for ~30 min. Paramud applications are usually covered by a non-permeable cover to conserve heat. The procedure is often claimed to result in moisturizing the skin and opening pores.

parting a mechanical property where a mineral breaks along a planar or near-planar structural weakness. Parting usually results from plane-like defects, often twinning, or is produced by anisotropic stress. In contrast, cleavage is a property of the periodic crystal structure. *Cf.*, cleavage

pearly having a luster similar to that of mother-of-pearl with an interplay of rainbow-like colors (iridescent)

peat a) Peat is partially decomposed plant (humus) matter that formed in a nominally oxygen-free, water-saturated environment, often found in northern regions where microbial activity is limited. Peat has more than 30% dry mass of dead organic matter ranging from colloidal masses to recognizable plant residues. b) In soil science, peat soil has a high content of plant-derived organic matter (humus), usually measured by the weight loss (or loss on ignition) by dry combustion in atmosphere. In peat soils, plant residues are recognizable. If the residual weight of an oven-dried (at 105-110 °C) soil after dry combustion at 440 °C is less than 75% of the weight of the oven-dried soil, then the soil is considered to be peat.

peat soil see peat

ped, primary A ped that can not be divided into smaller peds is a primary ped. Several primary peds may be packed together to form compound peds (referred to as secondary and tertiary peds). *Cf.*, ped

ped individual, natural soil aggregates composed of primary particles that form a soil structure. Adjoining peds are separated by planes of weakness formed by voids or cutans.

pedofeature A pedofeature refers to a unit fabric in a soil that is easily differentiated from the adjacent fabrics by a difference in concentration of a component, such as variations of chemical (e.g., organic, ferric iron, manganese) components, grain-size fraction, or internal fabric. The b-fabrics are commonly not considered as pedofeatures. See b-fabric, cutan, papule

pedoplasma see soil plasma

pedoplasmation production and redistribution (either physical or chemical) of soil plasma during soil formation and development. See soil plasma

peloid a maturated mud or muddy dispersion composed of a mixture of fine-grained material (commonly clay), mineral water (or sea water) and often organic compounds that result from biological metabolic activity, with healing and/or cosmetic properties. Peloids involve a maturation or ageing process, which may occur naturally, although commercially available peloids are often processed for weeks to several years in special ponds, typically containing mineral waters or brines of varying composition. Based on the composition of the fine-grained components, the terms inorganic peloid (phyllo-peloid, sulpho-peloid), organic peloid (organo-peloid), and mixed peloid have been proposed. Also, see mudtherapy, pelotherapy, peloid maturation. *Cf.*, ageing. *Syn.*, matured mud

Various types of peloids have been described:

natural peloid a healing mud formed in the natural sedimentary environment and used at the source. *syn.*, healing mud

phyllo-pelloid an inorganic peloid mostly composed of clay-sized phyllosilicates.
sulfo-peloid or *sulpho-peloid* an inorganic peloid mostly composed of sulfur or sulfide minerals.
organo-peloid a peloid composed primarily of organic-rich materials (e.g. peat).

peloid maturation a process that occurs with the intimate blending of fine-grained materials (commonly clays and/or organic material) with medicinal mineral water or sea water for variable periods of ageing. Biological activity during maturation may play a role in enhancing healing properties and in shortening ageing time. Cation exchange between minerals and water may also occur during maturation, affecting the fluid chemistry, and this may enhance the physical properties (e.g. plasticity) of the suspensions.

pelotherapy therapies involving the use of peloids (muds or poultices). *Cf.*, active principle, aesthetic medicine, antibacterial clay, geotherapy, healing clay, medicinal clay, peloid

peptize a) The formation of a stable dispersion of colloidal particles in water, usually by chemical additives; b) In bentonite clay-product manufacturing, the use of chemical additives to improve the performance characteristics of the clay for a particular end use. *Cf.*, peptized clay.

peptized clay a clay to which chemicals have been added to improve the performance characteristics of the clay for a specific end use. *Cf.*, peptize

percutaneous migration As applied to clay science, percutaneous migration refers to the diffusion of elements from clay poultices (peloids) through the skin.

peripheral replacement Replacement of a reactant mineral by a product mineral beginning at the outermost margin of the reactant mineral's grain or fracture-bounded remnants. See centripetal replacement.

perlite hydrated volcanic glass containing 2-5 wt. % H_2O. Because of their high viscosity, rhyolitic melts form glasses upon cooling. Devitrification produces a "perlitic structure", which is characterized by concentric cracks. Perlite has a pearly luster, and is glassy gray to black. When heated, H_2O is released and glass shards dehydrate and expand to volumes to 20 times their original size. Associated zeolites are common. Perlite, after heating, is used as aggregate, fillers, in plaster products and in light-weight concrete, as coatings for steel beams as fire protection to reduce the possibility of melting or partial melting, etc.

permanent charge see point of zero charge

permanent layer charge see layer charge

permeability In soil science, permeability is a property of a soil or porous medium, which expresses the ease of a fluid flow (e.g., water, crude oil, gas, or air) through the medium, given in units of (length)^2. In contrast, hydraulic conductivity refers specifically to water as the permeant. *Cf.*, hydraulic conductivity

petrographic microscope an optical (transmitted visible light) microscope with polarizing filters or prisms along the optical path. The petrographic microscope is commonly used to examine thin sections and grain mounts. See thin section, crossed Nichols, plane light.

pH the negative logarithmic ($\log_{10}$) measure of hydrogen ion (H^+) activity which defines the acidity or alkalinity of a solution. In pure water, a value of 7 is neutral and represents an exact balance between the activities of hydrogen (H^+) and hydroxide (OH^-) ions. Values lower than 7 represent an increase in hydrogen ion activity and are acidic. Values higher than 7 represent a decrease in hydrogen ion activity and are alkaline.

pharmacognosy The branch of knowledge concerned with medicinal drugs derived from natural products. This knowledge base includes the study of physical, chemical and biological properties of natural substances, for example, clays and clay minerals, used medicinally.

phase diagram a graphical representation of the relationships involving possible phases that occur in a system, typically based on parameters such as temperature (T), pressure (P), composition (X), and typically at equilibrium conditions. However, other parameters may be used where convenient and non-equilibrium diagrams may be useful to show important phase relationships.

phase a part of a system with distinct chemical and physical properties that is mechanically separable from other parts of the system

phenyltrimethylammonium organoclay see trimethylphenylammonium organoclay

phreatic surface the groundwater table in soil or sediment. The phreatic surface is the interface between the vadose zone (unsaturated water content) and the phreatic zone (saturated with water) of a soil/sediment, usually characterized with a zero porewater pressure.

phyllo-peloid see peloid

phyllosilicate a family of minerals contain continuous two-dimensional tetrahedral sheets of composition T_2O_5 (T = Si, Al, Be...) with tetrahedra linked by sharing three corners of each, and with a fourth corner pointing in any direction. The tetrahedral sheets are linked in the unit structure to octahedral sheets, or to groups of coordinated cations, or individual cations. Although continuous tetrahedral sheets often form six-fold rings, other ring configurations are considered part of the phyllosilicate family. See Guggenheim *et al.* (2006) and references therein. *Cf.*, clay mineral

physical weathering the breakdown of rocks to fragments through primarily non-chemical processes. Non-chemical processes may include, but are not limited to, ice and/or root wedging, thermal expansion, stress release (e.g., exfoliation), and physical consequences of crystal wedging, and volume change caused by hydration and/or dehydration. Physical weathering may be biologically influenced. See weathering, chemical weathering

pica a disorder involving the eating of material that does not have nutritional value. Pica is the more general term for the eating of odd things, such as clay, ice, hair, starch, etc. *Cf.*, geophagy

piezoelectric a property of crystals where an electric moment forms in proportion to tension or compression, with a reversal in polarity depending on the direction of the stress. The phenomenon is dependent on certain non-polar crystal classes or symmetries of the material. A "converse piezoelectric" effect is known where the crystal changes shape if an electric current is applied along the polar axis. Quartz exhibits piezoelectric and converse piezoelectric effects.

pillar see pillared clay

pillared clay a clay mineral intercalated with small organic or inorganic complexes (or "pillars"), which do not completely fill the interlayer space. The size and shape of the resultant cavities (or "galleries") are determined by the size, shape, and orientation of the pillars. Pillared clays are potentially useful to remove organic molecules based on shape-selective adsorption ("molecular sieves"). For clays, intercalations involve positively charged complexes (either organic or inorganic "cations") to offset the negatively charged layers of the clay. Common types of complexes include those of the methylammonium group (organic) and the Keggin ion (Al13, inorganic). Other types of layered materials can also be pillared. See Keggin ion. *Cf.*, zeolite

PL or **PPL** see plane light

plane in phyllosilicate mineralogy, a set of one or more types of atoms (e.g., a plane of Si and Al atoms, a plane of basal oxygen atoms) that form a two-dimensional flat or nearly flat surface. See Guggenheim *et al.* (2006) and references therein. *Cf.*, sheet, layer

plane light Polarized light, or plane light, is light that vibrates within a single plane ("plane of vibration") which is defined as the plane parallel to the ray's path and its vibration direction. The polarized light results from the introduction of a single polarizing device into the optic path of a petrographic (polarized light) microscope, with the plane of vibration obtained from the privileged direction of the polarizer. See petrographic microscope. *Abbr.* PL, or PPL (plane polarized light).

plane of vibration see plane light

plane polarized light see plane light

plasma, soil see soil plasma

plasma see soil plasma

plaster a mixture of lime, sand, cement, and water often used to protect ceilings or walls. The mixture hardens upon drying to form a hard surface in preparation for final finishing.

plastic limit one of the Atterberg Limit tests. The water content of an homogenous, fine-grained soil/water mixture where the mixture begins to exhibit plastic behavior upon deformation, as defined by the test method described in ASTM Standard D4318 - 05. Syn. "lower plastic limit". See Mitchell (1993). See also activity, Atterberg Limits, consistency number, liquid limit, plasticity index, shrinkage limit.

plasticity When referring to clay, this is a property where moistened material, when deformed under the application of pressure, will retain the induced deformed shape when the applied pressure is removed.

plasticity index the numerical difference between the liquid limit and the plastic limit; i.e., the difference between the water content of a fine-grained soil/water mixture at the boundary between its liquid and plastic states and the boundary between its plastic and brittle states, based on tests outlined by Atterberg and standardized by ASTM Standard D4318 - 05. See Mitchell (1993). Syn. Plasticity number. See also activity, Atterberg limits, consistency number, liquid limit, plastic limit, shrinkage limit.

plug flow reactor a column or cylindrical reactor used to describe the reaction kinetics within a continuous, flowing system. *Cf*., batch reactor, chemostat, continuously stirred tank reactor

pneumatolitic a petrologic term that refers to alteration or crystallization involving a gas phase, typically forming from cooling magma.

pneumoconiosis Pneumoconiosis is a lung disease caused by the inhalation of (mineral) dusts, characterized by lung inflammation, coughing and development of fibrous connective tissue (fibrosis). Examples of pneumoconiosis include silicosis, caused by respirable silica, and asbestosis, caused by respirable asbestos. Also see asbestosis, silicosis

podoconiosis derived from the Greek *podo* (foot) and *konia* (dust), and refers to a condition in which some nano-particles enter the bloodstream through skin causing a condition characterized by gross enlargement of areas of the body (mostly limbs) by blockage of the lymphatic system or by a non-parasite immune system response. This condition is similar to elephantiasis, which is caused by parasite blockage of the lymphatic system. *Syn*., nonfilarial elephantiasis

point of zero charge (pzc or zeropoint of charge) the pH value of a solution where the negative variable charge equals the positive variable charge for a mineral. The variable charge results from unsatisfied bonds at grain boundaries and any compensating negative (OH^-) or positive (H^+) ions, and thus is a function of the solution surrounding the mineral grain. The variable charge of a phyllosilicate involves the edges of the particle, whereas the layer charge is the "permanent charge" and not of interest in determining the point of zero charge ("total charge" is the sum of the variable and permanent charges). Surface properties change with the presence and types of ions satisfying the residual charges at the crystal surfaces. For example, the type of ions attaching to the surface can affect flocculation/dispersion properties and therefore, sedimentation rates. Sposito (1998) defines the point of zero charge more succinctly as “the pH value of a solution, where the net surface charge of a particle is zero”. The point of zero charge should not be confused with the “point of zero net proton charge”, which refers to particles where only protons are charge determining. The point of zero charge is not necessarily identical to the isoelectric point (iep), in part because of how they are derived experimentally. The point of zero charge is usually determined from titrations at various ionic strengths, which yield intersecting curves at a single point (the “common intersection point”) which, in the absence of sorption of other charge-determining ions, is identical to the point of zero charge. The iep is determined by electrokinetic methods as the pH where the particle mobility is zero. Both points are only identical if specific adsorption of other ions is absent.

point of zero net proton charge see point of zero charge

point group The ten basic operations (center of symmetry, mirror plane, proper and improper rotation axes) and their 22 allowable combinations (total = 32) are called “point groups” or “crystal classes”. A combination is allowable only if “closure” is produced. See “rotation symmetry” for the definition of “closure”.

point defect Point defects are structural imperfections that occur at a specific point within an atomic structure, and may produce a variation in the ideal chemical composition of the crystal. “Schottky defects” occur where a vacancy replaces a cation or an anion from their ideal sites in an atomic structure. In such cases, charge neutrality must be maintained, and thus for example, where a cation is replaced by a vacancy either higher valence cations must be substituted for lower valence cations or a corresponding anion must be replaced by a vacancy. “Frenkel defects” involves a misplacement of a cation (“cationic Frenkel defect”) from its site to an interstitial position where a site does not normally reside. Like the Schottky defect, the Frenkel defect must involve charge neutrality (for example, producing a “cationic Frenkel defect” and an “anionic Frenkel defect”). “Impurity defects” affect the chemical composition of the crystal and involve an atom or ion of a different type either in place of an atom or ion that belongs to the crystal or in an extraneous (interstitial) position. An “*F* center defect” in alkali halides involves a trapped electron in an otherwise vacant site that was formerly occupied by an anion. This defect is thought to cause a color change in the halide. *Cf.*, line defect

polarizability the ability of an atom, ion, or molecule to become polarized (where there is a distortion of its charge distribution). For example, an anion has greater polarizability than a cation because of the tendency of the electron cloud about an anion to be easily distorted by a local electric field. Generally, an anion is unable to hold its outer electrons tightly and therefore it is more readily polarizable than a cation.

For a monoatomic atom or ion and some molecules, the polarization vector $\mathbf{P}$ has the same direction as the applied electric field vector $\mathbf{E}$, and $\mathbf{P} = \alpha\mathbf{E}$, where α is the polarizability. If a molecule has an anisotropic polarizability, that is the polarization $\mathbf{P}$ may not follow the direction of the applied electric field $\mathbf{E}$, the polarizability α is a symmetric tensor, and the polarization $\mathbf{P}$ is given as:

$$\mathbb{P} = \begin{pmatrix} P_x \\ P_y \\ P_z \end{pmatrix} = \begin{pmatrix} \alpha_{xx} & \alpha_{xy} & \alpha_{zx} \\ \alpha_{xy} & \alpha_{yy} & \alpha_{zy} \\ \alpha_{xz} & \alpha_{yz} & \alpha_{zz} \end{pmatrix} \begin{pmatrix} E_x \\ E_y \\ E_z \end{pmatrix}$$

and because the polarizability tensor is symmetric: alpha(xy) = alpha(yx), alpha(xz) = alpha(zx), and alpha(yz)=alpha(zy). *Cf.*, polarization, dipole moment

polarization Polarization is the distortion of the charge distribution about an ion or molecule. In effect, the electron cloud about, for example, an anion can become distorted by a neighboring cation, thereby affecting their determined ionic radii. The anion, now polarized by the cation, shares its electrons with the cation and covalent character increases. Polarization may be temporary if the electric field is temporary, and thus a temporary dipole moment may form. *Cf.*, polarizability

polarized light see plane light

polymer a chemical compound composed of a very large number of atoms (often hundreds or thousands) forming chains, cycles or other structures. Polymers form by a polymerization process (typically with carbon or aluminum atoms) where smaller units are bound together to form larger units. According to IUPAC, a minor change of the number of integrated atoms does not cause a significant change in the properties of the polymer, and this characteristic distinguishes polymers from oligomers. In clay science publications, oligomers are commonly mistaken for polymers. *Cf.*, geopolymer, oligomer, polymerization

polymer-clay nanocomposite see clay nanocomposite

polymerization Polymerization is a process involving a poly-condensation reaction, where smaller units of atoms are bound together to form a chemical compound composed of larger numbers of these units. The resulting compounds are called oligomers or polymers. Synthetic geopolymers (geotechnical engineering), minerals forming various interlayer oligomers in hydroxy-interlayered smectite (clay/soil science), and silicate mineral formation (metamorphic geology) are some examples that involve the polymerization processes. *Cf.*, geopolymer, hydroxy-interlayered minerals, oligomer, polymer

polymorphism the ability of a given element or compound to crystallize in more than one form, with each form having a distinct crystal structure. *Cf.*, polytypism

polynuclear complex see binuclear complex

polytype refers to a structure that develops from layer-stacking sequences via polytypism. See *polytypism*

polytypism an element or compound in two or more layer-like crystal structures that differs in layer-stacking sequences. Polytypism differs from polymorphism in permitting small differences in chemical composition between structures, not to exceed 0.25 atoms per formula unit of any constituent element. Layer structures that differ from one another by more than this amount are to be called *polytypoids* rather than *polytypes*. (*Quot* Bailey, 1977) *Cf.*, polymorphism

polytypoid see polytypism

popcorn texture Popcorn texture is a term for a macro-texture observed on exposed and weathered clay surfaces commonly associated with deposits of sodium bentonite (usually on open-pit mine-faces, bed outcrops, or stockpiles). These high-swelling bentonites develop irregularly rounded lumps resembling mounds of popped corn caused by successive periods of swelling and shrinkage from the cyclical uptake and loss of water within the clay. See also alligator skin texture.

porcelain a high-strength and low-absorption ceramic whiteware of high quality made from milled clay (commonly kaolin), quartz, and feldspar, fired to 1200 - 1400°C. Porcelain mainly consists of glass with some mullite. Porcelain may or may not be glazed and is commonly used as table ware, vases, electric insulators, or art ware. *Cf.*, ceramic, glaze

pore see macropore, mesopore, and micropore

porosity the ratio of the void volume (empty space) in a material to its total volume (i.e., including particles and the empty space between the particles), usually expressed as a percentage. *Cf.*, void ratio

porostriated b-fabric see b-fabric

porphyric c/f-related distribution see c/f-related distribution

Portland cement a group of hydraulic cements composed of milled clinker usually mixed with calcium sulfate (commonly gypsum) as a set retarder. The most common Portland cement is called Ordinary Portland Cement (OPC). The name Portland cement was derived from the Isle of Portland, U.K., where Portland stone, which looked similar to cement, was quarried. Portland cement sets as a result of hydration reactions, and thus is required to be wet while curing for best stability (strength). *Cf.*, cement, binder, clinker

pottery see ceramic

poultice a moist, often medicated, mass applied to a wound or a painful area to reduce pain or to help in healing. The medicated mass may produce soothing vapors to aid in healing. Poultices are commonly hydrated clays, often bentonite. Poultices are also used to dissolve stains from porous decorative stone by the long-term application of a solvent via the poultice. *Syn.*, cataplasm

pozzolan a rock or artificial material composed of amorphous SiO2 (or silica and alumina), clay minerals, carbonate phases, iron compounds, and feldspars. Pozzolan forms a binder at ambient temperatures if mixed with $Ca(OH)_2$ and water due to hydraulic reactions and the formation of calcium silicate hydrate (CSH) phases. Natural pozzolan is usually rich in clay minerals and soluble silica, commonly tuff with volcanic glass (silica) or sedimentary rocks with hydrated amorphous forms of silica (e.g., opal). Artificial pozzolan is often composed of milled bricks or fly ash. Pozzolan is a common additive for mortar and concrete. Cf., calcium silicate hydrate (CSH) phases, brick, concrete, mortar

pozzolana Pozzolana is a naturally occurring siliceous or siliceous and aluminous pozzolanic material or pozzolan with a volcanic origin. *Cf.*, pozzolan, pozzolanic activity

pozzolanic activity Pozzolanic activity is the degree or extent of the chemical reactions in Portland cement and other amorphous aluminosilicates (e.g., metakaolin, some volcanic ashes, fly ash) between a pozzolan and dissolved $Ca(OH)_2$, usually measured in terms of reaction time or reaction rate. *Cf.*, pozzolan, pozzolana

preconsolidation stress the maximum effective stress to which a clay deposit has been subjected during its entire formation and consolidation process, including any natural processes (e.g., sedimentation, compaction, uplift, ground water fluctuation) or man-made loading or unloading events (e.g., groundwater pumping, construction). Thus, the preconsolidation stress is the maximum value of all past and current effective stresses that have caused the clay to consolidate. The maximum past effective stress is generally determined experimentally by measurement of one-dimensional elastic and plastic deformation that occurs during consolidation, or one-dimensional stress-strain compression curves, or from known events, such as specific sea-level changes, groundwater table fluctuations, etc. *Syn.*, preconsolidation pressure; *cf.*, overconsolidation ratio

preconsolidation stress pressure see preconsolidation pressure

preconsolidation pressure the maximum consolidation pressure or stress that a clay mass has ever been subject to, including the current stress acting on the clay. *Syn.*, preconsolidation stress, maximum consolidation stress/pressure

primary mineral A primary mineral is a mineral of igneous, metamorphic or sedimentary origin now residing in weathering, sedimentary, diagenetic or hydrothermal environments where many alteration processes operate. A primary mineral is present in the parent rock; thus, in soils and other weathering or alteration environments, a primary mineral is one that remains from the parent rock whereas a secondary mineral is one that forms as the rock weathers. *Cf.*, secondary mineral

prismatic a crystal shape where one dimension is considerably greater than the other two

proper rotation axis see rotation symmetry

pseudoglobular microfabric see microfabric, clay

pseudomorph A pseudomorph is an alteration product of a crystal that preserves the external euhedral crystal form of the precursor mineral. The pseudomorph may have a different chemical composition and/or crystal structure than the precursor crystal. The pseudomorph can result from replacement of the original structural bonds by formation of new bonds that minimize the energy toward equilibrium in response to changes in the chemical (T, P, X) environment. *cf.,* alteromorph, centripetal replacement

pseudotrilayer see alkylammonium organoclay pseudotrilayer

pyroelectric a property of crystals where an electric dipole moment develops in response to a temperature change. The material cannot exhibit temperature gradients, and the property diminishes over time at temperature. Only polar crystal classes exhibit this property. An analogous magnetic property, “pyromagnetism”, can also exist.

pyromagnetism, see pyroelectric

pyrometric cone a pyramid with defined dimensions made from certain ceramic materials with different resistances to heat, used as indicators for time-temperature conditions in a kiln. Two or three pyrometric cones are placed in a kiln next to a ceramic material which is to be fired. During heating each cone softens at certain time-temperature conditions leading to a gradual kinking of each cone. Pyrometric cones are often called Seger cones named after the modern inventor of pyrometric cones, Hermann August Seger, a German silicate chemist.

pzc see point of zero charge

quantum calculation a calculation of atomic or molecular properties of a model system based on first principles (*ab initio*) quantum mechanics. Because quantum calculations involve either the solution or approximation of the Schrodinger equation to determine the electronic structure, this is the highest level of theory that can be used to calculate molecular-scale properties of a model system. *Cf.*, density functional theory

quasi-coating In micromorphology of soils, quasi-coating is a pedofeature that consists of a layer of material related to surfaces (i.e., voids, grains, aggregates) but not immediately adjacent to the surface. *Syn.*, quasi-cutan. *Cf.*, hypo-coating

quasi-cutan see quasi-coating

quaternary phosphonium salt a quaternary organic salt based on the phosphonium (PH_4^+) ion. Tetramethyl phosphonium chloride is the phosphonium analog of tetramethyl ammonium chloride. *Cf.*, quaternary alkylammonium salt

quaternary alkylammonium salt alkylammonium salts, such as hexadecyltrimethylammonium bromide, have four alkyl or methyl groups attached to nitrogen with a permanent positive charge. The similar n-hexadecylamine hydrochloride used in the alkylammonium layer charge method is only positively charged in neutral to acidic solutions. See alkylammonium layer charge method

quick clay Landslide-prone, silty-clay to clayey-silt size sediments that become liquid upon failure (shear strength <0.5 kPa). Pre-failure strength exceeds post-failure strength by 30 (minimum) to hundreds of times. Quick clay is not thixotropic; it cannot reform after failure. ‘Quick clay’ applies only to the undisturbed material.

Quick clays of Scandinavia, Eastern and Western Canada, and Alaska developed in fine-grained, glacial rock flour that accumulated in marine and brackish water during Pleistocene glacial retreat (Torrance, 2012). The salt induced a flocculated microstructure that gained strength as additional sediment accumulated. The water content approximates the high-salinity liquid limit of the sediment. Quick clays in the down-glacial-flow direction from the magnetite-rich, iron-ore deposits of Quebec and Labrador gained unusually high undisturbed strengths owing to iron-oxide cementation. Isostatic uplift elevated the deposits above sea level, and an oxidized weathered crust formed. In broad, level areas, downward percolation of rain displaced the salty pore waters. In areas adjacent to uplands, artesian pressures have displaced the salt upwards to the surface drainage system. The oxidized zone is thinner where salt removal was upward than where it was downward. During salt removal, the structure and water content remained nearly unchanged, whereas the liquid limit of the sediment decreased to its low salinity value, and the liquidity index increased from about 1.0 (high salinity) to 1.2 – 4+ (low salinity). At liquidity indices >2, the thoroughly disturbed material flows like motor oil.

Chemical, mineral and microstructural factors are critical to quick-clay development. The mineralogy must be dominated by “low activity minerals” (illite, chlorite, quartz, feldspars, amphiboles, iron oxides, and carbonates). Other requirements include: flocculated microstructure (salt-induced), leaching of salt (which decreases the liquid limit), and reducing conditions that inhibit the formation of swelling clays. Experiments to produce quick clay using ‘pure’ clay, such as illite, have been unsuccessful, but using dispersed material from what had once been ‘quick clay’ has succeeded. Whereas non-swelling phyllosilicates must be present, clay-sized primary minerals also appear to be necessary.

A mineralogical variant is a quick clay that developed contemporaneously in marine sediment in Japan that is dominated by low-activity (<1.1), high-ferrous-iron, non-swelling clay, and volcanic ash (Torrance and Ohtsubo, 1995). However, where oxidizing conditions develop that allow conversion of the ferrous iron to ferric iron to decrease the layer charge sufficiently to produce a swelling smectite, the resultant liquid-limit increase renders the oxidized zone no longer ‘quick’. *Cf.*, liquid limit, liquidity index, plasticity index, quick-clay landslide, shear strength, thixotropy, Udden-Wentworth scale.

quick-clay landslide A landslide in which quick clay plays an important role. They usually start with a small triggering landslide along a riverbank or terrace, but may also be triggered by human actions or earthquakes. “Flow quick-clay landslides” occur where a substantial depth (a few meters, or more) of quick clay underlies a relatively thin surface-weathered zone. Flow failures commonly occur stepwise and retrogressively over a substantial time period (minutes to more than an hour). The liquid debris carries the thin crust out of the landslide scar and along the river valley. Very little debris remains within the scar. Flows are the norm in Scandinavia and constitute about half of the quick-clay landslides in eastern North America. In “spread quick-clay landslides”, the non-quick overburden is thicker and the large chunks of crust are difficult to transport. Once failure is initiated, the failure plane advances rapidly into the quick-clay zone and, as the quick clay liquefies and starts to move, the overburden breaks into a series of slices that are oriented perpendicularly to the direction of movement. In most cases, a large proportion of the landslide debris remains within the landslide scar. Ridges of nearly intact slices alternate with zones of liquid and plastic debris to create a ribbed, horst and graben-like topography. Spread-type landslides are rapid (tens of seconds to minutes in length). *Cf.*, quick clay

Ramsdell-style notation for chlorite a method commonly used for chlorite where a set of related polytypes is designated by a single name, usually a species name (e.g., clinochlore, chamosite) or the group name (in this case, chlorite), followed by a structural symbol suffix that defines the layer stacking differences. Unlike the Ramsdell-style notation for phyllosilicates, the chlorite notation was developed for one-layer polytypes; although multi-layer chlorite polytypes are known, they are rare. The first part of the symbolism (I or II) designates the orientation of the interlayer sheet, the italicized second part (*a* or *b*) describes how the interlayer sheet cations project on to the hexagonal ring of the adjacent 2:1 layer, and the third part (1 through 6) indicates how the next 2:1 layer resides relative to the interlayer sheet. Although there are 24 possible combinations of regular one-layer polytypes, only 12 of these are unique. A dash separates the second and third parts of the symbol, when the third part can be determined. Some polytypes do not have 2:1 layers that are symmetrically disposed about the interlayer, in which case the second part of the symbol may be given as *ab* or *ba*. Examples: clinochlore-II*b*-4, chamosite-I*bb*, pennantite-I*a*. *Cf.* Ramsdell-style notation

Ramsdell-style notation a method commonly used to describe phyllosilicates, where a set of related polytypes is designated by a single name, usually a species name or a group name, followed by a structural symbol suffix that defines the layer stacking differences (after Guinier *et al.*, 1984). The symbolism is based on the number of layers (first part of the suffix), which is followed by an italicized capital letter that defines the crystal system: *C* (= cubic), *H* (= hexagonal), *T* (= trigonal with hexagonal Bravais lattice), *R* (= trigonal with rhombohedral Bravais lattice), *Q* (= quadratic or tetragonal), *O* (= orthorhombic, previously *Or*), *M* (= monoclinic), and *A* (= anorthic or triclinic, previously *Tc*). A subscript "d" indicates disorder and a subscript "1" or "2" indicates that another polytype exists with the same number of layers and symmetry. *Cf.* Ramsdell-style notation for chlorite

reaction order The order of a reaction is empirically observed and determined by the sum of the powers of the concentrations of the rate equation. If the rate of a reaction, R, is proportional to the concentration of one species, R = k[A], where k = constant and [A] = concentration of species A, then this is a first-order reaction. A second-order reaction may have a rate equation of R = k[A][B] for two reactants, A and B, and the powers of each sum to 1 + 1 = 2. Sometimes, the rate determining step can be deduced from knowing the reaction order of a series of reactions.

reciprocal lattice The reciprocal lattice, first constructed by P. Ewald, involves a set of points, each of which represents a set of planes in space, 1/*d* from the origin. The value of *d* is the spacing between a set of planes in a unit cell. This lattice is useful to better visualize a diffraction pattern and its geometric relationship to the unit cell of the crystal under study. The relationship is obtained from the modified Bragg equation ($1/d_{hkl} = 2\sin\theta/\lambda$), which is the condition where a possible X-ray reflection can occur. Thus, the point located at 1/*d* represents the cross-section of the pole of this set of planes, *hkl*, and corresponds to a possible X-ray reflection from the crystal. The unit cell as determined by the reciprocal lattice (referred to as the "reciprocal unit cell"), by construction, is defined in relation to the unit cell of the atomic structure (referred to as a the “direct cell” or “real cell”) of the crystal under study: *a** is perpendicular to the plane containing *b* and *c*, *b** is perpendicular to the plane containing *a* and *c*, and *c** is perpendicular to the plane containing *a* and *b*, where the * (referred to as “star”, as in “*a* star”, “*b* star”, etc.) indicates a reciprocal lattice measurement. *Cf.*, crystallographic axis, Bragg’s law

recrystallization a) *Senso stricto*. solid-state transformation(s) of crystalline material to another crystalline material. In this process, larger, more defect-free grains result than the predecessor grains. Although the bulk composition does not change, the resultant assemblage may be of the same mineralogy or different (e.g., polymorphs) mineralogy. In rocks, this is a mechanism by which plastic deformation can ultimately produce, via recrystallization, an assemblage of strain-free grains. It is unclear if recrystallization is truly “solid state” because the process may involve the formation in inter-granular fluid films. A “secondary recrystallization” also can result where there is an increase in particle size of grains by subsuming neighbors. It is unlikely that clay minerals transform in this manner; low-temperature transformations involving clays usually require the presence of water. b) *Senso lato*. Conversion of pre-existing chemical and mineralogical composition (either crystalline, poorly crystalline, or amorphous) either to new crystalline material of the same mineralogy or to a new phase assemblage, commonly involving limited amounts of aqueous fluids. For clays, the crystal-surface energy to crystal volume is reduced to drive recrystallization, even at low temperatures. See Ostwald ripening

reduced cell see unit cell

reflection see mirror plane

refractory clay see fire clay, refractory material

refractory material A refractory material retains its chemical and physical properties at high or very high temperatures (ASTM, v. 15.01 indicates high temperature at >1,000 ºF). The high-temperature materials are generally non-metallic and are commonly composed of, but not limited to, oxides of aluminum, calcium, magnesium, and silicon. Refractory materials are common in linings for furnaces, kilns, and incinerators, and are used in some crucibles. Fire clays are often used to manufacture refractory materials. See fire clay

regolith crustal material above unweathered bedrock, including unweathered rock where it is entirely surrounded by unconsolidated or weathered natural material. The term is not related to the geologic age of the bedrock, the individual constituent materials of the regolith, or the formation or assembly of the ensemble of constituent materials.

regular volatile matter (RVM) an industrial term referring to dehydration of untreated, porous clay until it contains between ~5 - 20 wt % free moisture, with dehydration achieved by heating below or near the boiling point of water (< 105 °C) to preserve the integrity of the clay and to create empty pore spaces so that the material may resorb fluids.

rehydroxylation the reincorporation of (OH) groups from water (suspension) or air (humidity) into the structure of a clay mineral, previously lost during dehydroxylation. *Cf.*, dehydroxylation

Reichweite (or R, R0, R1, etc.) literally means “the reach back”. The expression of both the probability of finding a B layer after an A layer in a two-component system of layers containing A and B layers, and the influence A has on the identity of the next layer, after Jadgozinski, 1949. When flipping a coin, R is equal to 0 because there is no influence at all of one flip on another. The probability of getting a head depends only on the proportion of heads and tails, in this case 0.5, and thus there is a null relation between the influence of A on B. For perfect order of 50% I (illite) and 50% S (smectite) layers, ISISIS... the R = 1. A sequence of ISII... is R = 3, with one S layer surrounded by three I layers. Common usage is R0 for R = 0, R1 for R = 1, etc.

relative humidity see humidity

relict soil a soil formed on a preexisting landscape under a previous pedogenetic regime, and not subsequently buried by geologically younger materials. See also paleosol.

remolded quick clay “Remolded quick clay” refers to the material after the flocculated microstructure of the quick clay has been destroyed. By definition, remolded quick clay behaves as a liquid. The flow properties of remolded quick clay are required for analysis of the flow behavior of landslide debris as it leaves the landslide scar and flows. Most remolded quick clays behave in the ‘modern viscometric’ thixotropic manner of shear resistance increasing and decreasing, respectively, as the shear rate increases and decreases. The change is never more than a trivial portion of the quick clay strength prior to collapse. Remolded silt-rich, quick clay may exhibit extreme dilatancy at high shear rates, leading to shear blockage. *Cf.*, quick clay, quick clay landslide, dilatancy

residual strength The residual strength is the shear resistance or the capacity of a clay, soil, or rock to withstand significant pressure that develops after strain-softening at large strains. Residual strength is controlled by the characteristics of the internal failure surface where either significant particle movements have occurred (as in soils) or the fracture interface is the peak failure surface (as in rocks). The residual strength is typically smaller than the peak failure strength of a clay, soil, or rock.

residual soil soil formed in place by in-situ weathering of parent rock material. *Cf.*, sedimentary clay.

reticulate a texture visible at hand-specimen or thin-section scale in which one generation of secondary minerals or soil plasma is arranged in a net or network geometry. See soil plasma

reticulate striated b-fabric see b-fabric

rheology the study of the deformation and flow of materials. For clay scientists, this may involve the study of the plasticity (i.e., creep, rupture) of clay, clay-water interactions, clay suspensions and interparticle forces, the electrical double layer, etc.

rheopexy a property of a non-Newtonian fluid where the viscosity of the fluid increases with time at constant shear rates and shows a reduction in viscosity over time if not agitated (e.g., stirred). *Cf.*, Newtonian fluid, quick clay, thixotropy

rotation symmetry symmetry involving a repetition of features about an axis. The axis type may be either a one-fold, two-fold, three-fold, four-fold, or six-fold axis, where the angle of repetition may be determined by 360/n, where n is equal to the axis type (1, 2, 3, 4, or 6). A one-fold rotation axis is the identity operation. Another name for this type of axis is "proper rotation axis". *Cf.*, symmetry, rotoinversion axis

rotation axis see rotation symmetry

rotational stacking disorder Phyllosilicates commonly show rotations between adjacent layers involving *n*60° (where *n* is an integer from 1 to 6), and with registry or partial registry between layers. Stacking disorder or partial disorder involves the lack of regularity in the *n* value. Equivalence to this type of stacking order/disorder may be achieved also by random or partially random translations along the pseudohexagonal *a* or *b* axes (commonly along *a*, and very rarely along *b*) of the layer silicate. See *turbostratic stacking*

rotoinversion axis A general type of symmetry axes that involves a rotation followed by an inversion operation, with a repeating set of rotation/inversion operations until "closure" (returning to the starting position in the rotation/inversion or repetition process) is reached. The one-fold rotoinversion axis ($\overline{1}$) is equivalent to a center of symmetry, and the two-fold rotoinversion axis ($\overline{2}$) corresponds to a mirror plane; only the latter are used, respectively. In addition, the $\overline{3}$ implies that the object possesses a center of symmetry and a 3-fold axis and a $\overline{6}$ is equivalent to a 3-fold and a mirror plane perpendicular to it. Thus, only the $\overline{4}$ is a unique symmetry operation. *Cf.*, symmetry

rubification a weathering process wherein minerals in a soil release iron which subsequently precipitates to form free iron oxides, such as hematite (red) and goethite (yellow brown), to produce reddening of a soil horizon.

RVM see regular volatile matter

safety glass see tempered glass

saprolite A residual, sedentary, *in situ* regolith developed by chemical weathering of rocks, most often primary crystalline (igneous and metamorphic) bedrock. Saprolite preserves parent-rock textures in the form of abundant, predominantly argillaceous, and commonly pseudomorphous weathering products of individual primary minerals. Preservation of parent-rock mineral textures and fabrics in saprolite is often associated with high microporosity and may be a consequence of isovolumetric weathering. Saprolites are typically some meters thick but can be hundreds of meters thick.

saturation see saturation (water)

saturation index a measure of how far from equilibrium a solution is with respect to a given mineral. The saturation index, SI, is determined from $SI = Q/K_{eq}$, where Q is the reaction quotient and Keq is the equilibrium constant, often given as $\log_{10} (Q/K_{eq})$. When $SI = 0$, then the system (water + mineral) is at equilibrium, if $SI < 0$, the mineral will dissolve, and if $SI > 0$, then the mineral will precipitate.

saturation (water) the condition where the voids within a material are filled with water. The degree of water saturation is the ratio of pore water volume to the total pore volume, usually expressed as a percentage.

Schottky defect see point defect

screw axis symmetry involving a rotation about an axis followed by a translation parallel to the axis. The rotations correspond to a 2-, 3-, 4- or 6-fold axis and requires a translation following each rotation. The symbol for a screw axis is n_m, where n is the rotation component and m/n is the translation component. For example, in a 4_1 screw axis, the translation is 1/4 of a unit cell and the rotation corresponds to a 4-fold axis. Thus, symmetry consistent with a 4_1 screw axis is generated by a 90 ° rotation followed by a 1/4 cell translation, with the process continuing until closure. Cf., rotation symmetry, rotoinversion axis, symmetry, unit cell

screw dislocation see line defect

seat rock a rock or sedimentary layer underlying a coal bed with physical characteristics suggesting that it served as a soil which supported the vegetation that produced the coal. (Modified from Huddle and Patterson, 1961)

sedimentary clay In civil engineering, a clayey soil formed by transport and sedimentation of particles by water, air, or ice. Loess is an example of a sedimentary soil because it forms via wind transport and sedimentation. Sedimentary marine clay forms by deposition of fine-grained particles through seawater.

septechlorite an invalid term, use kaolin-serpentine group (Bailey, 1980)

seat earth a British term for underclay *Cf.*, underclay

secondary crystal growth crystal growth from nanoparticles to larger particles that occurs by an assembly of aggregates, sometimes known as "oriented attachment".

secondary mineral a mineral formed by an alteration process; the chemical constituents of a secondary mineral may be derived from the decomposition of a primary mineral and/or derived from outside the system during the alteration process. *Cf.*, primary mineral

Seger cone see pyrometric cone

self-activating clay an organoclay + organic solvent with an optimum gel strength that has not been augmented by additives, such as polar molecules (e.g., ethyl alcohol, acetone, propylene carbonate). See gel strength, organoclay

self-dispersing clay Self-dispersing organoclays are clays that have additives to develop viscosity at much lower shear and energy input than other, non self-dispersing organoclays. An example of additives to form an appropriate complex are EDTA(ethylenediaminetetraacetic acid) and dimethyldihydrgenated tallow quaternary ammonium. This molecule intercalates into the organoclay and props the interlayer open to allow exfoliation.

sensitivity (St) A geotechnical term that evaluates the degree of strength loss when natural silty-clay and clayey-silt size sediments are thoroughly disturbed by natural or human actions. Sensitivity (St) of sediments is the ratio of the undisturbed in-situ shear strength to the shear strength after thorough remolding. Generally, the higher the sensitivity, the greater the geotechnical challenge, for example, in leading to flow landslides or excessive consolidation.

sepiolite-palygorskite group a group name for phyllosilicates with characteristics that are dominantly fiber-like, but with some plate-like character. The atomic structure has continuous planes of basal oxygen atoms (thus forming the plate-like character) with the apical oxygen atoms of the tetrahedra pointing alternatively in opposite directions away from the basal plane. The tetrahedral apices link to partial octahedral sheets, discontinuous along one direction but infinite in the other, to form a pattern of octahedral ribbons (thus forming the dominant fiber-like character). These minerals are classified as modulated phyllosilicates. The width of ribbons may vary, which leads to different numbers of octahedral cation sites per formula unit (5 for palygorskite, 8 for sepiolite).

serpentine-kaolin a group name for platy phyllosilicates of 1:1 layer and a layer charge of ~ 0 per formula unit. Generally, the *d*(001) spacing is approximately 7.1-7.3 Å. The group is further divided into subgroups that are either trioctahedral (serpentine) or dioctahedral (kaolin), and these subgroups are further divided into mineral species based on chemical composition. The 1:1 layers are bonded by long hydrogen bonds (~2.9 Å) and possible coulombic interactions between the octahedral sheets of one layer and the tetrahedral sheet of the adjacent layer. See "group names".

sesquan see cutan

shale Shale is a mudrock with a high proportion of clay and silt sized particles, that usually exhibits lamination and fissility. When blocky and non-fissile the mudrock is named mudstone. *Cf.,* mudstone.

shear strength In soil science, shear strength is a measure of the ability of a soil to resist failure along a surface when subjected to a critical combination of shearing and normal forces. The shear strength has cohesive (commonly related to clay content) and frictional components (related to the interaction of angular particles). Pore water pressures also play a role.

sheet For phyllosilicates, a sheet refers to corner-sharing linkages of tetrahedral coordination polyhedra (i.e., tetrahedral sheet) or edge-sharing linkages of octahedral coordination polyhedra (i.e., octahedral sheet). For a tetrahedral sheet, three corners of a tetrahedron are shared with other tetrahedra and the fourth corner may point in any direction. See Guggenheim *et al.* (2006) and references therein. *Cf.*, tetrahedral sheet, octahedral sheet, layer

shrinkage a ceramics industry term describing the reduction in size of a solid body relating to dehydration during initial drying and/or devolatilization during the final firing stage of making the ceramic body (e.g., bricks, whiteware, sanitary articles, porcelain, and stoneware).

shrinkage limit The shrinkage limit is the boundary water content that separates the semi-solid state of clay from its solid state in the classification of a fine-grained soil. At this water content, further drying of the clay does not cause a change in its total volume (i.e., no shrinkage). However, if the water content is greater than the shrinkage limit, drying causes the clay to shrink. The shrinkage limit is one of the three Atterberg Limits (i.e., liquid, plastic, and shrinkage limits). *Cf.*, Atterberg Limits

SI International System (of units); Système International d'Unités

silan see cutan

silane coupling agent a class of reagents characterized by a central silicon atom coordinated tetrahedrally to four R groups. Such compounds are commonly used to bond an inorganic substrate, such as clay minerals, to a polymer. In the most reactive form, two or three of the R groups are chlorine atoms and the remaining are organic groups. The chlorine atoms in these compounds are very reactive with water and hydrolyze readily to form condensation polymers with Si-O-Si backbones, or the chlorine atoms can react with hydroxyl groups on clay mineral surfaces with loss of HCl. A less reactive form has two or three of the R groups as methoxy or ethoxy groups with the remaining R group being another nonlabile organic group. These silanes can be hydrolyzed to form similar polymers or reactions with hydroxyls on clay minerals, but generally require heat and vacuum to drive the condensation reaction. These agents allow the surface of hydroxyl containing compounds to be converted to hydrophobic or reactive surfaces depending on the character of the organic R group.

silanol group a surficial SiOH group, which is able to incorporate or dissociate protons. A ferronol group (FeOH) is an additional surface group that behaves similarly to an aluminol or silanol group. See *aluminol group*

silica Silica refers to SiO_2 chemical composition only and the term does not connote structure. The term commonly is used to describe a mineraloid or a glass, as in a silica-rich glass. Thus, silica does not specifically refer to quartz or opal (but opal has a structure involving small, non-crystalline silica spheres). *Cf.*, mineraloid

silica fume a synthetic, poorly crystalline/amorphous SiO_2 product composed of spheres of <<1 m in diameter, and thus with a large specific surface area. Silica fume is a by-product of the

Si and FeSi alloy production and used as an additive for concretes or geopolymers. *Cf.*, cement, geopolymer

silicosis lung fibrosis caused by the inhalation of dust containing crystalline silica (SiO2) in any of its forms (e.g., quartz, cristobalite, tridymite, coesite, stishovite).

silt A general term for any non-consolidated, clast-rich material that consists of >50% primary particles with diameters of 4-63 µm (American geologists), 2-63 µm (European geologists), or 2-50 µm (American soil scientists). See siltstone

siltstone A sedimentary rock with primarily silt-size components; siltstone rocks may show sedimentary structures, such as flow structures and cross-bedding. Siltstones are often, but not always, chemically cemented. See mud, mudstone, silt

sintering bonding of powdered material by solid-state reactions at temperatures lower than melting.

site energy energy required to separate an ion an infinite distance from its equilibrium position in a crystal. In calculating an electrostatic site energy, the site energy is the sum of all the Coulombic and all the repulsive energies between the ion in the site and all neighbors in the unit cell.

skeletal microfabric see microfabric, clay

slag, blast-furnace a waste product from the iron-producing industry, sometimes used as a substitute for metaclay to produce geopolymers. Blast-furnace slag is produced when pure iron is separated from the silicate-containing byproducts. These byproducts are quenched rapidly in water to obtain a highly reactive material with a poorly crystalline to amorphous (glass-like) structure. *Cf.*, geopolymer, metaclay

slake see slaking

slaking the breakdown of large soil or clay material aggregates (typically >2-5 mm) or fine-grained sedimentary rock rich in clay into small particles (<0.25 mm) when rapidly immersed in water. Slaking occurs when aggregates are not sufficiently strong to withstand internal stresses caused by rapid water uptake into the pore structure or fabric of the aggregate. Internal stresses result from differential swelling of clay particles, trapped and escaping air from pores, rapid release of heat during wetting, and the mechanical action of moving water. Slaking is influenced by the presence of smectitic clays (either smectite, especially Na-montmorillonite, or interstratified clay with a smectite component) that shrink when dry and swell when wet. Organic matter often reduces slaking by binding the particles or by slowing the rate of surface wetting.

slip See blunging

smectite a group name for platy phyllosilicates of 2:1 layer and a layer charge of ~ -0.2 to -0.6 per formula unit. Generally for natural samples, the *d*(001) spacing is approximately 14.4-15.6 Å, although other spacing may occur depending on H_2O retention and interlayer occupancy. The group is further divided into subgroups that are either trioctahedral (according to Bailey, 1980, this subgroup name is "saponite") or dioctahedral (subgroup name of "montmorillonite", according to Bailey, 1980), and these subgroups are further divided into mineral species based on chemical composition. Guggenheim *et al.* (2006) did not give subgroup names. Smectite minerals have large specific surface areas (10 - 700 m^2/g) and exhibit a high expansion (swelling) capability in the presence of H_2O. Smectite and vermiculite minerals are often referred to as "swelling" or "expandable" clay minerals. Cation-exchange capacity or solvation of polar molecules is large. Smectite is commonly a primary constituent of bentonite (see bentonite for respective genesis information) and pelitic sediments (e.g., shales) and occurs in soils. Prior to *circa* 1975, the smectite group was called the montmorillonite-saponite group, but this nomenclature was abandoned because of the confusion between the use of the same name for both a group and species. Very early (Kerr and Hamilton, 1949), smectite was used as a term for fuller's earth (initially), montmorillonite, and certain bentonitic clay deposits. See "group names".

smectite-to-illite transition the conversion of smectite to illite involving a significant change in the chemical composition of the 2:1 layer from a smectite-like composition to an illite-like composition. The resulting net negative charge on the layer must become sufficiently large to preferentially fix potassium or other large cations and cause dehydration of the interlayer. The process of conversion may be one of apparent solid-state transformation or mostly in the solid state or apparent neoformation via a solution. The degree of conversion may be useful to understand crystallization parameters during burial diagenesis or metamorphism (e.g., Hower *et al.* (1976) or hydrothermal activity (e.g., Inoue *et al.,* 1987). *Cf.,* illite/smectite

smoke see suspension

soil plasma In soil science, plasma refers to fine-grained (too fine to resolve individual constituents by visible-light microscopy) crystalline or amorphous materials in soils, which includes saprolites. See saprolite, clay groundmass, *Syn.* pedoplasma

soil, residual in soil science, describing soil formed in place by in-situ weathering of rock parent material. *Cf.*, clay (sedimentary).

sol or **clay solution** see suspension

solid emulsion see suspension

solid foam see suspension

solid solution isostructural phases that show a compositional variation whereby one or more ions can substitute at a specific atomic site in a crystal structure. In fact, the ions can also be elements or ionic groups, and it is possible that more than one atomic site may be involved. A common type of "substitutional solid solution series" shows ~~a~~ miscibility between two end members, with permissible variations in composition between these two end members. For example, olivine $(Mg,Fe)_2SiO_4$, represents a chemical variation (i.e., solid solution) between two end members, forsterite Mg_2SiO_4 and fayalite Fe_2SiO_4, where Mg and Fe can substitute for one another in two atom sites. The chemical formula may be written as $Mg_{2-x}Fe_xSiO_4$, where x represents the Fe content, and this value can vary between 0 and 2.0. Other types of solid solutions include "interstitial solid solution" where atoms may reside in interstices between the ideal locations of the atoms of a structure and "omission solid solution" where a site is incompletely filled. "Limited solid solutions" may occur where the compositional variation does not range entirely between the two end members. In addition, two or more substitutions ("coupled substitutional solid solution") may occur over multiple sites so that the requirement of overall charge neutrality in a phase is satisfied, for example, where $Na^+ + Si^{4+}$ substitute for $Ca^{2+} + Al^{3+}$ in the plagioclase feldspar structures between end members albite, $NaAlSi_3O_8$, and anorthite, $CaAl_2Si_2O_8$.

solid solution, **coupled substitutional**, see solid solution

solid solution, **interstital**, see solid solution

solid solution, **limited**, see solid solution

solid solution, **omission**, see solid solution

solid solution, **substitutional**, see solid solution

solid-state diffusion a process of mass transfer where atoms, ions or molecules move through a solid. *Cf.*, absorbent, adsorbate, cation exchange

solidus in a phase diagram, the solidus describes the upper limits where only solid phases exist. *Cf.*, liquidus, phase diagram

soluan see cutan

soluble salts Unprocessed clay samples commonly contain soluble salts, including chlorides, sulfates, and carbonates, which should be removed either prior to analysis or prior to drying or firing. Such salts can inhibit deflocculation, and they may interfere with the determination of particle size. In addition, they may prevent the preferred orientation of clay-mineral aggregates in preparation for some X-ray analysis procedures. During drying, soluble salts migrate to the clay body surface and can interfere with glazing; after firing, these salts can cause efflorescence.

sorbent a generic term for materials displaying a high degree of absorptive and/or adsorptive physicochemical properties, often useful in consumer or industrial applications.

Southern Bentonite Initially, an industrial or commercial term, designating calcium bentonite from Mississippi, USA. This material exhibits characteristics of low water adsorption, dilation, viscosification and high green-sand binding strength. Use of the term has broadened to include any bentonite having performance characteristics equal to that of high quality calcium bentonite from Mississippi. Whereas the term “Southern Bentonite”, and its synonyms, continue to have meaning in the industrial and commercial realm, they are scientifically obsolete and should not be used in that context. syn: Mississippi Bentonite

space group the symmetry used to describe a three-dimensional crystal structure, including both translation-free symmetry operators, translational symmetry (i.e., screw axes and glide planes), and Bravais lattices. There are 230 space groups. In mineralogy, Hermann-Mauguin symbols are used, whereas in chemistry and spectroscopy, Schoenflies symbolism is used to characterize the different combinations of symmetry elements.

specific heat capacity see heat capacity

specific gravity a dimensionless physical parameter used to measure the relative density of solids, including minerals and soils. Specific gravity is the ratio of the unit weight (or density) of a solid to the weight (or density) of an equal volume of water at 4 °C.

speckled b-fabric see b-fabric

spectroscopy the study of the interaction of radiation with matter

sponge microfabric see microfabric, clay

spray drying a drying technique used in clay science primarily to minimize preferential orientation of clay mineral particles for analysis by X-ray diffraction methods. Spray drying involves high dispersion of a solid (i.e., clay), usually suspended in ethanol or a water-soluble organic binder (i.e., Polyvinyl Alcohol 72,000), where the binder is subsequently evaporated. Although effective, the process usually involves large sample sizes (typically grams). In industrial applications, spray drying is used to economically produce commercial quantities of dried clay having a controlled aggregate particle size, from a liquid clay suspension, without the need for mechanical grinding.

spread quick-clay landslide see quick-clay landslide

stability constant see intrinsic stability constant

state function In thermodynamics, a state function is one that is not dependent on the path (i.e., history) that the system has undergone and is only dependent on the state of the system as determined by temperature, pressure, volume, etc. at a particular moment.

Stern layer Helmholtz and later Stern divided the solution side of a diffuse double layer into an inner part (Stern or Helmholtz layer) and an outer part (Gouy or diffuse layer). In a more simple model, the ions with a finite size "d" adsorb on a surface and form a so-called outer Helmholtz plane. In the so-called triple layer model, the Helmholtz plane is subdivided into an inner

Helmholtz plane (iHp, where specifically adsorbed ions such as protons or K on high-charged clay minerals reside) and an outer Helmholtz plane (oHp, where non-specifically adsorbed ions reside). Note that for all models the following equation holds:

Sigma_zero + Sigma _iHp + Sigma_oHp + Sigma_diffuse = zero.

where: Sigma_zero denotes the charge density (in Coulomb per square meter) of the solid, Sigma_iHp denotes the charge density of species adsorbed in the inner Helmholtz plane (usually specifically adsorbed ions), Sigma_iHp denotes the charge density of species adsorbed in the outer Helmholtz plane (usually nonspecifically adsorbed species), and Sigma_Diffuse is the charge density of the diffuse double layer formed in the solution. See diffuse double layer

stipple-speckled b-fabric see b-fabric

Stokes' law a mathematical expression that describes how a spherical particle, nominally less than 20 micrometers, settles in a viscous fluid. This equation is used in clay science, although clay particles are generally flat plates and not spherical, and thus fall at slower velocities than spheres of equal density as calculated using Stokes' law. *Cf.*, equivalent spherical diameter

stoneware see ceramic

strata plural of stratum; see stratum.

stratum a layer of sediment or sedimentary rock (pl. strata).

stress, effective soil see effective stress, soil

stress history a process describing how a clay or soil experiences different loading or unloading conditions in the past. The maximum past effective stress is generally determined experimentally by measurement of one-dimensional elastic and plastic deformation that occurs during consolidation, or one-dimensional stress-strain compression curves, or from known events, such as specific sea-level changes, groundwater table fluctuations, etc. Usually, stress history is used in combination with overconsolidation or overconsolidation ratio. *Cf.*, overconsolidation, overconsolidation ratio

stress path the graphical representation of the loading or unloading processes that a clay has experienced in a triaxial stress condition. The stress path is usually plotted in the coordinate system of mean effective stress and shear stress. The mean effective stress is the average of the vertical and horizontal effective normal stresses, whereas the shear stress is the difference between the vertical and horizontal effective normal stresses.

strial b-fabric see b-fabric

striated b-fabric see b-fabric

structure the accepted atomic, ionic, and molecular arrangement of atoms of a material. (*Quot* Guggenheim *et al.*, 2006)

structured clay A structured clay is a clay that exhibits stiffened or strengthened behavior, usually caused by microstructure features, such as cementation, aggregation, ageing, or flocculation. Usually, a structured clay exhibits a higher yield stress, Young's modulus, and failure strength than a non-structured clay. Re-sedimentation of the same material in the laboratory usually destroys the in-situ structure formed in the natural, non-processed clay.

subcell see supercell

subhedral see crystal

sublimation the physical process where a solid phase transitions directly to a gas phase without going through a liquid phase.

submerged unit weight see unit weight, effective

sulfo-peloid see peloid

supercell A supercell exists if the unit cell contains a subunit (or subcell) whose periodicity is smaller than that of the parent lattice (Nespolo, 2019). Therefore, the supercell consists of multiple translations of the subcell. However, the supercell is more complex than the simple translations of the subcell units because of offsets in the translations of the subcell, relaxation effects in the bonding within subcells, or more complex structural changes in one or more subcells. A crystal with a supercell structure will display extra diffraction peaks (or superlattice reflections) with respect to its subcell structure. In molecular simulations, a "supercell" is created by multiple repeats of a subcell equal to the periodicity of the unit cell. Calculations are then made on the supercell, which may deform the connectivity of the atoms within the subcell(s), resulting in a change of the subcell periodicity within the supercell. This supercell minimizes the effect of nearest neighbors in adjacent cells. *Cf.*, unit cell

superheating an industrial term for the fast (seconds to minutes) high-temperature heating (usually 900 – 1000 °C) of porous clays or perlites to remove adsorbed water by volatilization, in addition to partial dehydroxylation (structural water) of the clay minerals present. For most clay minerals, the point where the rapid loss of structural water first occurs is often referred to as the onset of low volatile matter (LVM) characteristics. Termination of heating at this or a somewhat higher temperature commonly generates a material (e.g., calcium hydroxide) whose porous bulk fabric remains intact and which does not readily slake in water. Unlike calcination, which implies a complete dissociation reaction, superheating produces limited dehydroxylation without destroying plasticity (i.e., without destroying clay-like properties). Thus, LVM clays will still display a measurable weight loss on ignition. *Syn*., flash heating, *Cf.*, low volatile matter (LVM); slake; calcine; loss on ignition; water, adsorbed; water, structural; water, zeolitic

surface complexation There are two kinds of surface complexes, one with no H_2O molecules interposed between it and the mineral surface, termed an inner-sphere complex, and one in which at least one H_2O molecule is interposed, and this is termed an outer-sphere complex (Sposito, 1989). Inner-sphere complexes are chemically bonded; outer-sphere complexes or those that exist in the diffuse layer are said to by physically adsorbed (Parks, 1990).

surfactant a wetting agent that lowers the surface tension of a liquid or lowers the interfacial tension between two liquids. Detergents are an important economic group of wetting agents that can affect clay surfaces.

surface a boundary, planar or near planar, between two phases. The term is often used to connote planar or near planar interfaces between a condensed phase (solid) and gases, liquids, or other solids, or between any two phases (e.g., liquid-liquid, gas-gas, liquid-gas). Surfaces generally have an interfacial energy term and a chemical compositional gradient existing from the surface, and a discrete molecular entity or multi-component substance may exist on or at the surface. In clay science, clay surfaces include "external surfaces" where there are broken bonds at particle edges and "internal surfaces" at the junction between the layer and the interlayer. The external surfaces include the broken-bond particle edges and the terminating basal surface. Internal surfaces, although a term commonly used in clay science, may not strictly adhere to the above definition because the material (or lack of material) in the interlayer is not necessarily a "phase", but the atomic arrangement (or its behavior) in the interlayer is sufficiently distinct from the layer that the term is useful (e,g., the discrete molecular entity or multi-component substance addressed above). Internal surfaces are readily accessible to the environment outside the particle (often owing to the small particle size) and may have characteristics consistent with the permanent layer charge of the particle and interlayer cation size and charge. Environmental characteristics, such as water activity (e.g., pH, relative humidity), solute concentration, etc., may influence the behavior of the internal surface. External surfaces are also affected by environmental characteristics, but often the broken bonds affect the characteristics/structure of the electrolyte nearest the external surface. *Cf.*, interlayer, layer, phase

surface-controlled growth dissolution 'surface controlled' growth or dissolution requires the rate-determining step in the growth or dissolution reaction to occur at the mineral surface; this rate-determining step is in the form of an attachment to or a detachment from the surface of a metal or metal-ligand 'activated complex.'

suspension A two-phase system with a solid ("dispersed phase") dispersed in a fluid ("continuous phase"). In colloid chemistry, a suspension differs from a colloidal suspension (or "sol") by having particles >1µm. The term "suspension" is preferred over "clay solution" or "colloidal solution" to avoid confusion with true solutions, which do not have an interface. Thus, the presence of an interface between the solid and the liquid phase (in the thermodynamic sense) is important. The table below lists names for systems with dispersed phases. See blunging.

swelling clay mineral a clay mineral that can sorb large amounts of water and thereby expands in volume. Both vermiculite and smectite are swelling clay minerals. *Cf.*, swelling clay.

swelling clay a clay that can sorb large amounts of water and thereby expands in volume. The swelling clay minerals, smectite and vermiculite, if they occur as fine-grained material, are referred to as "swelling clays". In industry, bentonites are commonly referred to as "swelling clay". Some clays that are referred to as "swelling clays" have been shown to be dominated by clay minerals characterized by interstratifications of two varieties of phyllosilicate layers, one being expandable via adsorption of H_2O and one not, as in “swelling chlorite” which is interstratified chlorite and smectite. *Syn.*, expandable clay; *Cf.*, swelling clay mineral

symmetry is used to describe an object with a systematic repetition of features, and is particularly useful to describe crystal shapes or atom locations in an object

symmetry plane see mirror plane

syngenetic material formed contemporaneously with rocks that are associated or enclose material

syntaxy a geometrically fixed intergrowth between two phases. Originally defined as between two polymorphs only and extended to include an oriented intergrowth between any two phases. *Cf.*, epitaxy, topotaxy

system a region of space within the universe. Systems are considered in thermodynamic or other studies to determine how a change in the environment (e.g., temperature changes, pressure changes, etc.) will affect the system. Systems may be closed by encapsulating in noble metals, placing a liquid in a sealed beaker, etc. A “closed system” is affected only by receiving energy from or giving energy to the outside environment. An “open system” differs from a closed system by an exchange of matter, in addition to energy. An “isolated system” receives neither matter nor energy across the boundary.

system, closed see system

system, isolated see system

system, open see system

Table of descriptive names for systems with dispersed phases (after Hiemenz and Rajagopalan, 1997)

Continuous phase	Dispersed phase	Descriptive names (* recommended)
gas	liquid	aerosol*, fog, mist
gas	solid	aerosol*, smoke
liquid	gas	foam
liquid	liquid	emulsion
liquid	solid	suspension*, sol, colloidal solution, gel
solid	gas	solid foam
solid	liquid	gel, solid emulsion
solid	solid	alloy

tactoid In the context of polymer/clay nanocomposites, a tactoid is any collection of “primary” (i.e., the smallest division of the phyllosilicate particle that retains the chemical character of the compound, either a 1:1 or 2:1 layer), colloidal-size clay particles, which are essentially acting as a unit.

tailings see gangue

talc layer inappropriate usage for a 2:1 layer, see *layer*

talc-pyrophyllite a group name for platy phyllosilicates of 2:1 layer and a layer charge of ~ 0 per formula unit. Generally, the *d*(001) spacing is approximately 9.1-9.4 Å. The group is further divided into subgroups that are either trioctahedral (talc) or dioctahedral (pyrophyllite), and these subgroups are further divided into mineral species based on chemical composition. The layers are bonded by weak van der Waals interactions. See "group names"

Tatatila-type montmorillonite A term first used by Schultz (1969) to describe a montmorillonite with the same chemical characteristics of the Chambers-type montmorillonite (i.e., a total net layer charge of -0.85 to -1.20 per unit cell $[O_{20}(OH)_4]$ with a layer-charge contribution from tetrahedral substitutions of between -0.15 to -0.50), but with higher temperatures of dehydroxylation at 710-730 ºC rather than at 660-690 ºC. Use of this term is obsolete. See Chambers-type montmorillonite. Terms used in this obsolete classification are: Wyoming-type, Otay-type, Chambers-type, Tatatila-type, beidellite-type (ideal and non-ideal), and non-ideal montmorillonite. Current nomenclature for montmorillonite is that it is an Al-rich, dioctahedral smectite with an ideal structural formula of $(Al_{3.15}Mg_{0.85})Si_8O_{20}(OH)_4X_{0.85}.nH_2O$ with layer charge from primarily octahedral substitutions of Mg.

tempered glass glass that has been heat treated in a specific way such that its thermal properties and mechanical strength are improved. This treatment often involves heating to near the glass softening point followed by controlled cooling, resulting in a glass that will break into granular fragments rather than sharp plates. Such glass is also known as "safety glass."

tenacity resistance to breaking or deforming a crystal

tensile strength the maximum stress developed in a material by a pulling load at the point of rupture, given as a load per cross sectional (e.g., kg per cm^2)

terra cotta unglazed or glazed building blocks of either low- or high-fired clay, typically used as ornamental features on buildings

terra rosa a red glaze made from hematite

tetracalciuminate see calcium silicate hydrate (CSH)

tetragonal see crystal system

tetrahedral layer inappropriate usage for a tetrahedral sheet. See *tetrahedral sheet*

tetrahedral sheet A tetrahedral sheet contains continuous two-dimensional corner-sharing coordination tetrahedra involving three corners and the fourth corner pointing in any direction. The tetrahedral sheet generally has a composition of T_2O_5 (T = Si, Al, Fe^{3+}, Be, B...). After Guggenheim *et al.* (2006); see also references therein. *Cf.*, octahedral sheet

tetrasilicic an invalid term, previously used as a classification of the micas where the number of silicon atoms per formula unit is four per four tetrahedral sites, see Rieder et al. (1998). *Cf.*, mica, true mica, brittle mica, interlayer-deficient mica, group names

thermal diffusion see diffusion. *Cf.*, thermal conductivity

thermal conductivity rate of heat flow through a material. Heat flow is given as a unit of cross sectional area, per unit of temperature and time along the direction of heat flow.

thermal analysis the recording of the change in temperature and/or mass of a material when heated.

thermal expansion the change in volume of a material with increase in temperature. It is often expressed as the coefficient of thermal expansion, which is the degree of expansion divided by the change in temperature.

thermally activated clay a clay treated by heating (to dehydroxylation temperatures) to increase reactivity (e.g., as a preparation step to form geopolymers). During thermal activation, the clay minerals (partly) dehydroxylate resulting in distorted structures with broken bonds, which increases reactivity. *Syn*., metaclay. *Cf.*, activated clay, firing

thermodynamics the study of energy (potential, kinetic and internal energy) and its conversion to heat (involving work, determining forces, energy transfer, etc.) to characterize systems. Chemical thermodynamics considers energy changes that occur from reactants to reaction products or with physical changes of state during a chemical reaction. Thermodynamics considers macroscopic qualities (temperature, pressure, volume, composition, etc.) and does not provide mechanistic (atomic theory, atomic structure, molecules, etc.) understanding.

thin section Material, such as a sliced piece of mineral material, rock material, or soil material, that is mounted on a glass microscope slide, and placed in the optical path of a polarizing (petrographic) microscope is referred to as a “thin section”. The standard thickness of the material mounted on the glass is 30 μm. See petrographic microscope.

thixotropic ageing a unique time-dependent process where a material (usually a colloid, gel, dispersion, suspension, soft clay) under conditions of constant volume, composition, and temperature becomes stiffer and stronger with time without external physical, chemical, or mechanical disturbance/input. It is generally believed that the change in certain physico-chemical intermolecular and/or interparticle forces as well as microstructure (e.g., particle contacts, reorientation, and aggregation in a clay suspension) contributes primarily to the thixotropic hardening. Such thixotropic ageing or hardening process usually occurs in a material that has been subjected to remolding or mechanical disturbance. A thixotropically aged material can soften or liquify again upon re-remolding and even undergoes cycles of stiffening and softening upon resting and remolding, respectively, without involving the change in composition, temperature, or volume.

thixotropy a) In the classic sense, thixotropy refers to a material that exhibits reversible sol-gel-sol-… behavior. For example, 'chemically modified' bentonite drilling muds used by the petroleum industry are thixotropic. The property prevents the granular material ("cuttings") produced during drilling from settling out when drilling is stopped (briefly, or for substantial periods), thus preventing the drill rod from seizing. b) The 'modern viscometric' meaning refers to the increase in shear resistance when the shear rate is increased, and the decrease when the shear rate is reduced. Most thoroughly dispersed clay materials above some relatively low concentration exhibit this phenomenon. *Cf.*, dilatancy, Newtonian fluid, quick clay, rheopexy

tile a glazed or unglazed ceramic plate made by firing milled clay (e.g. kaolin) and quartz, plus added feldspar, carbonates, and/or fluorite. Tiles are commonly used in roofing, walls, floors, mosaics, and art. *Cf.*, ceramic, glaze, earthenware, stoneware, kaolin

tonstein A kaolinite-rich rock formed by alteration of glassy volcanic ash or tuff deposited in an organic-rich aqueous environment, such as those associated with coal-forming environments.

topotaxy a geometrically fixed intergrowth between a reactant and one or more of its products which resulted from a solid-state transformation. Different authors have suggested that the product phase(s) should maintain orientation a) of most atom positions or b) of symmetry axes of the reactant phase. c) The reaction involves conversion throughout a single crystal. *Cf.*, epitaxy, syntaxy

total charge see point of zero charge

trace element Mineralogical term: an element found in small quantities in a mineral and not considered essential because it is not required for the structure to exist. A trace element is not quantitatively defined, but is generally considered to be <1wt. %. b) Medical/biological term: an element that occurs in animals or plants in small quantities and is required for physiological health. *Cf.*, essential trace element

***trans*-vacant** A *trans*-vacant phyllosilicate is dioctahedral with the vacancy ordered to the site where the OH,F anions are on opposite octahedral corners (i.e., *trans* orientation). *Trans* sites are located on the mirror plane of an ideal layer in a phyllosilicate. *Cf.*, *cis*-vacant

triclinic see crystal system

transformation The phenomenon by which primary minerals in general, and chain silicates and phyllosilicates in particular, alter usually by weathering to secondary minerals through the direct incorporation and reuse of some part of the structure of the parent mineral. Products of transformation reactions are often pseudomorphous or alteromorphous after the primary reactant (parent) mineral, and often exhibit regular crystallographic and orientation relations with the reactant mineral. See neoformation, inheritance

Transition State Theory (TST) If an energetically unstable complex is present, TST states that a transitional state, or activated complex, occurs. This activated complex is a transitional state between the reactants and products, and is considered a hypothetical way to develop or explain the kinetics of, most commonly, a single-step (elementary) chemical reaction. The transitional state represents an energy barrier that must be overcome for mineral growth or dissolution. *Cf.*, molecularity

transparent describes a material that allows radiant energy to pass through it without significant adsorption, scatter or reflection. *Cf.*, opaque, translucent

tri,dioctahedral chlorite a species of the chlorite mineral group that would have a trioctahedral 2:1 layer and a dioctahedral interlayer. There are no known chlorite structures of this type. Bailey (1988) described franklinfurnaceite, which has Ca between the 2:1 layer and the interlayer and thus is not a true chlorite, as tri,dioctahedral if the Ca is not considered. *Cf.*, dioctahedral chlorite, di,trioctahedral chlorite, trioctahedral chlorite, dioctahedral sheet, trioctahedral sheet

trimethylphenylammonium organoclay Low-charge smectite (e.g., SWy-1, SWy-2) treated with trimethylphenylammonium chloride (= phenyltrimethylammonium chloride) or trimethylammonium chloride yield organoclays that can effectively remove nonionic organic contaminants from water (Lee et al., 1990; Jaynes and Boyd 1990).

trinuclear complex see binuclear complex

trioctahedral sheet In the ideal case, the smallest structural unit contains three octahedra. If two such sites are occupied with cations and one site is vacant, then the octahedral sheet is considered “dioctahedral”. If all three sites are occupied, the sheet is considered “trioctahedral”. (*Quot* Guggenheim *et al.,* 2006; see also references therein). A trioctahedral sheet generally contains predominantly divalent cations. *Cf.*, dioctahedral sheet

trioctahedral chlorite a species of the chlorite mineral group with trioctahedral sheets only. This is the common form of chlorite. *Cf.*, dioctahedral chlorite, di,trioctahedral chlorite, trioctahedral sheet

triple layer model see Stern layer

trisilicic an invalid term, previously used as a classification of the micas where the number of silicon atoms per formula unit is three per four tetrahedral sites, see Rieder et al. (1998). *Cf.*, mica, true mica, brittle mica, interlayer-deficient mica, group names

true mica a group name for platy phyllosilicates of 2:1 layer and a layer charge of ~ -1.0 per formula unit. True micas do not show swelling capacity. Rieder et al. (1998) defines the true micas as having greater than 50% of the interlayer cations as univalent cations. The true mica group is further divided into subgroups based on the octahedral sheet being either trioctahedral or dioctahedral. *Cf.*, mica, brittle mica, interlayer-deficient mica, group names

TST see Transition State Theory

turbostratic stacking In phyllosilicates, turbostratic stacking involves highly disordered (non regular) stacking arrangements of layers where there is no registry from one layer to another, much like a stack of playing cards lying flat on each other but with no alignment of edges. Smectite minerals and halloysite commonly have turbostratic stacking. See rotational stacking disorder

turbulent microfabric see microfabric, clay

Udden-Wentworth scale The Udden-Wentworth scale (often referred to as the Wentworth scale) is a size scale (diameter) for clasts and is used primarily in sedimentology and related disciplines. The Udden-Wentworth scale considers size only and does not imply composition. The "clay" term in the scale has the potential to be confusing because "clay" is defined in clay mineralogy as having specific properties unrelated to particle size alone. Thus, to avoid confusion, use of "clay size" instead of "clay" is recommended here to delineate size characteristics of particles only. Further divisions, such as "fine", "medium", "coarse", etc. may be used also. Pettijohn (1957) discusses the history of the use of size terms, alternative classification schemes, and modifications to the nomenclature. See clay

Udden-Wentworth scale (after Pettijohn, 1957)

Grade	Scale
boulders	>256 mm
cobbles	64 - 256 mm
pebbles	2 - 64 mm
sand	1/16 to 2 mm
silt	1/256 to 1/16 mm
clay	<1/256 mm

underclay a fine-particle sedimentary seat rock composed mainly of clay minerals, that is generally non-bedded and contains traces of plant roots. Kaolinite-rich underclay deposits are economically important for ceramics manufacturing. (modified from Huddle and Patterson, 1961) *Cf.*, seat rock, ball clay, flint clay, fire clay

undrained shear strength the peak shear resistance or shear stress of a clay or soil that experiences no loss in pore water when subject to loading or unloading. When the applied stress exceeds the undrained shear strength, the clay or soil fails without drainage or exchange of pore water with materials outside the clay/soil mass.

undrained shear the loading and shearing of a clay or soil where the pore fluids are confined. Thus, during undrained shearing of a clay, the pore fluid pressure may change, but the total clay volume does not change.

unit cell A unit cell is the smallest repeating parallelipiped (= reduced cell) that contains the atomic structure of a crystal. The unit cell contains a crystals full symmetry and chemical composition and is chosen with cell edges (*a*, *b*, *c*) coinciding with any symmetry axes present. The unit cell is determined by X-ray diffraction, usually from a single crystal. *Cf.*, cell parameters, unit structure, X-ray diffraction.

unit structure For phyllosilicates, the unit structure is the total assembly of the layer and any interlayer material. After Guggenheim *et al.* (2006) and references therein. *Cf.*, layer, interlayer material

unit weight, effective In soil science, for saturated soils or soils beneath the groundwater table, the effective unit weight is the difference between the total unit weight of the soil mass and the unit weight of water. Thus, the effective unit weight removes the effect of the pore water within the soil mass. One difficulty in its measurement is the determination of loosely held H_2O between clay layers vs H_2O between grains (i.e., pores). *Syn.*, buoyant unit weight, submerged unit weight.

van der Waals forces van der Waals forces are residual forces between atomic groups or molecules and are comprised of primarily dispersion and dipole-dipole forces. Dispersion forces, or London forces, involve the temporary formation of polarity where one side of an atom (or molecule) may have more electrons at a given moment than the opposing side. Thus, one side is slightly more negative than the other slightly more positive side (by having a deficiency in electrons). Neighboring atoms have similar polarity, and a weak bond is formed where opposite charges between atoms attract each other.

variable layer charge see layer charge

Vegard's law describes a solid solution series where there is a linear relationship between the lattice parameters and the chemical composition (as atomic percentage). The term "law" is a misnomer because a linear relationship often does not exist.

vermiculite a) a group name for platy phyllosilicates of 2:1 layer and a layer charge of ~ -0.6 to -0.9 per formula unit. Generally for natural samples, the *d*(001) value is approximately 14.4-15.6 Å, although other spacings may occur depending on H_2O retention and interlayer occupancy. The group is further divided into subgroups that are either trioctahedral or dioctahedral and these subgroups are further divided into mineral species based on chemical composition. Both vermiculites and smectites have swelling capabilities. Distinguished from smectite in that Mg-exchanged vermiculite has *d*(001) of 14.5 Å after glycerol solvation, whereas smectite has *d*(001) of 17.7 Å. Vermiculite occurs in soils, and are most common in subtropical and temperate climates. b) an industrial/commercial commodity obtained from heat-treated naturally-occurring material composed of hydrous phyllosilicates (e.g., vermiculite, hydrobiotite, biotite). This material is heated rapidly to high temperature to cause exfoliation by volume expansion to produce an expanded product of low bulk density. The product involves an intimate mosaic-like intergrowth of dehydrated or partially dehydrated layers and thus is a heterogeneous mixture of phases. The product resembles vermiculite (*senso stricto*) primarily based on its physical properties, such as density, some adsorptive properties, and chemical composition. See "group names"; see intumescence. *Cf.*, smectite

vibrational spectroscopy a method of measuring intramolecular or intracrystalline modes of motion (vibrational modes) by observing the interaction of incident radiation with a sample. Common techniques used to obtain spectra are infrared and Raman spectroscopy, and inelastic neutron scattering. *Cf.*, spectroscopy, normal mode

Vickers hardness the measured hardness of a surface as tested using a special diamond pyramid-shaped indenter under various loads. A Vickers number is reported based on surface area indented (in mm^2) divided by pressure (in Newtons). *Cf.*, hardness, Mohs hardness

virgin clay A general term used in the pelotherapy clay industry to denote an unmodified ("raw") clay from a deposit, before maturation with saline or mineral water.

viscosity a measure of the resistance of a fluid to flow when the fluid is placed under stress

vitreous glassy luster *Cf.*, luster

vitrification The process of changing a solid, often crystalline material, into an amorphous glass-like material by heating the solid to its melting point followed by sufficiently rapid cooling and solidification so that short-distance atomic ordering resulting in recrystalization does not occur. As vitrification proceeds, the porosity decreases. Devitrification is the reverse process.

void ratio the ratio of the empty space (void volume) of a soil or geomaterial to the volume of its solid particles. *Cf.*, porosity

water, adsorbed or **(H_2O^-)** H_2O molecules attracted to internal or external surfaces of a phyllosilicate, or other material, and adhered to these surfaces in thicknesses of one or more molecules. The term "water" (rather than "H_2O") is not precisely used here because "water" is a (liquid) phase. Elevated temperatures, typically 110 °C for 12 hours, can desorb the adhered H_2O. However, for phyllosilicates, a temperature of 110 °C may not liberate all the adsorbed water molecules present, and temperatures of as high as 300 °C (in special cases, even higher) may be needed for some vermiculites and smectites. syn. absorbed water, *Cf.*, water, structural

water, combined see water, structural

water content, soil The degree of soil water content is defined by the fraction, by mass or weight, of pore water relative to the total dry soil solid particles, usually expressed as a percentage. In practice, soil water content is measured by heating a wet soil sample at 105 - 110 °C to a constant mass. The weight loss by heating is assumed to be the weight of water, and the residual weight is the weight of dry soil solids. *Syn.*, moisture content *Cf.*, water saturation, degree of;

water, crystallization of see water, structural

water, degree of saturation The degree of water saturation is the ratio of pore water volume to the total void volume, usually expressed as a percentage. In soil science, values may range from 0 % for a dry soil to 100% for a soil with its void fully occupied by water. Water saturation of a soil refers to the latter. See also water content

water, hydration of see water, structural

water, hygroscopic H_2O adsorbed by soil that is equilibrated with the atmosphere to which it is exposed at a given temperature and relative humidity, usually 25 °C at 98 % relative humidity.

water, interlayer water (or more precisely, H_2O molecules) adsorbed between the (1:1 or 2:1) layers of a phyllosilicate. The use of "water" is a misnomer because the interlayer H_2O is not equivalent to bulk water (i.e., a phase, a liquid), which involves randomly oriented H_2O. Instead, the interlayer H_2O is affected structurally by the adjacent 1:1 or 2:1 layers and by the cations present in the interlayer. *Cf.*, water, adsorbed

water, lattice see water, structural

water, molecular see water, structural

water, structural or **(H_2O^+)** water (more precisely, H_2O or OH molecules) that is directly bound to cations at crystallographic sites in a crystal structure. This H_2O or OH is capable of being driven off at elevated temperature, generally by heating to 1000 °C. For phyllosilicates, structurally bound "water" is in the form of hydroxyl (OH) groups coordinated to cations, and the high temperature is required to promote dehydroxylation. Fluorine and certain other anions may be driven off at these temperatures also. However, hydrates, such as gypsum ($CaSO_4 \cdot 2H_2O$), have structural water coordinated to cations as H_2O (e.g., water of hydration) that is liberated by heating to relatively low values, 65 - 95 °C. syn. combined water, molecular water, structurally bound water, water of crystallization, water of hydration. "Lattice water" is also used, but is not recommended because a "lattice" refers to a collection of identipoints, see "lattice". *Cf.*, water, adsorbed

water, structurally bound see water, structural

water, zeolitic water molecules adsorbed within the cavities/tunnels of the zeolite framework structure, commonly removed by heating at 350 to 400 °C for about 12 hours. "Zeolitic water" was a term used by early workers to describe interlayer water of phyllosilicates. However, the analogy is imperfect (and not in use anymore) because the number of interlayer water molecules affects the layer-to-layer spacing of a phyllosilicate, whereas the shape and size of zeolitic tunnels are not significantly affected by the number of H_2O molecules present. *Cf.*, water, structural; water, adsorbed

weathering the physical (mechanical) and/or chemical breakdown of rock, sediment, and soil in place under the influence of the hydrosphere and/or atmosphere. Biota may influence or control physical or chemical weathering. See physical weathering, chemical weathering. *Cf.*, erosion

Wentworth scale see Udden-Wentworth scale

western Bentonite An industrial or commercial term, originally used to designate the high quality sodium bentonite from Wyoming, USA. This material exhibits characteristics of high water adsorption, dilation, viscosification and dry sand binding strength. Usage of the term has since broadened to include any bentonite having performance characteristics equal to that of high quality sodium bentonite from Wyoming. Whereas the term "Western Bentonite", and its synonyms, continue to have meaning in the industrial and commercial realm, they are scientifically obsolete and should not be used in that context. syn: Wyoming Bentonite, Wyoming Sodium Bentonite, Wyoming-Type Bentonite

whiteware any ceramic that fires to a white or ivory color, commonly used in wall tiles, tableware, etc.

Wulff rule The Wulff rule or Gibbs-Curie-Wulff Theorem states that when the surface free energy of a crystal is minimized at equilibrium conditions, the perpendicular distance from a given crystal face to the center of the crystal divided by the surface free energy of that face is a constant for all faces of the crystal.

Wyoming bentonite an obsolete term, see western bentonite

Wyoming sodium bentonite an obsolete term, see western bentonite

Wyoming-type montmorillonite As described by Schultz (1969) based on chemical and thermal analysis, Wyoming-type montmorillonite is a type of montmorillonite characterized by a small net negative layer charge of about -0.35 to -0.85 per $O_{20}(OH)_4$, with tetrahedral substitutions causing from -0.15 to -0.50 of the total layer charge and specific thermal properties. Current nomenclature for montmorillonite is that it is an Al-rich, dioctahedral smectite with an ideal structural formula of $(Al_{3.15}Mg_{0.85})Si_8O_{20}(OH)_4X_{0.85}.nH_2O$ with layer charge from primarily octahedral substitutions of Mg, whereas beidellite has a net layer charge that occurs from tetrahedral substitutions of Al, with an ideal structural formula of $Al_{4.0}(Si_{7.15}Al_{0.85})O_{20}(OH)_4X_{0.85}.nH_2O$. Although the structure of a mineral is important (not given here), thermal properties are not part of the definition. The Wyoming-type montmorillonite of Schultz (1969) is best described as an intermediate in the montmorillonite-beidellite series. The term"Wyoming-type montmorillonite" is obsolete and should not be used.

Wyoming-type bentonite an obsolete tern, see Western bentonite

X-ray diffraction The interaction of X-rays (electromagnetic radiation with wavelengths in the approximate range of 0.1 to 10) with matter produces scattering in all directions. The electrons in the matter oscillate to the electric field of the impinging X-rays so that the scatter will be in the same wavelength and frequency of the impinging X-rays. Under certain conditions (defined by the Bragg equation), parallel rays produced by the scatter reinforce each other to produce a diffracted wave, and this is referred to as X-ray diffraction. *Cf.*, Bragg equation, unit cell

xenobiotic substances foreign to a body or an environment, for example, clay in the blood system.

yielding the phenomenon where a clay undergoes the transition from a purely elastic deformation stage to an elasto-plastic deformation stage. Yielding marks the onset of plastic deformation, and the stress at which yielding occurs is called yield stress or yield strength.

Young's modulus a measure of the response of a homogeneous material to uniaxial tension or compression, in units of pressure (usually gigapascals), obtained from the slope of the (linear) relationship of stress versus strain in the elastic regime. *Cf.*, elastic constants

zeolite a family of hydrated aluminosilicate minerals with a three-dimensional Si,Al tetrahedral framework-type structure with molecular-size channels and cages. Rings of four, six and eight tetrahedra are common structural subunits of the framework. The "extra-framework" content includes cations and H_2O; the cations are often exchangeable and the H_2O may be dehydrated or partially dehydrated. The tetrahedra are occupied by >50% Si, as required by the Lowenstein Al-avoidance rule; in some cases, Be is present. Zeolites are used commercially in ion-exchange, molecular-sieve, and hydration-dehydration applications.

zero point of charge see point of zero charge

zpc see point of zero charge

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